FORUM

ISASI

Air Safety Through Investigation

JANUARY–MARCH 2014

Journal of the International Society of Air Safety Investigators

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As discussed in *Safety Data: The Agony and the Ecstasy of Their Use* (Page 6), data mining has played a key role in decreasing the airline accident rate over the past two decades. More recently, it has helped to quickly solve particularly complex incidents and accidents, such as the Boeing 777 dual-engine roll back and subsequent short landing to a London (Heathrow) runway on Jan. 17, 2008. Photo: Crown copyright by courtesy of the AAIB and Metropolitan Police ASU.

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Air Safety Through Investigation

Journal of the International Society of Air Safety Investigators

Volume 47, Number 1

Publisher Frank Del Gandio
Editorial Advisor Richard B. Stone
Editor Esperison Martinez
Design Editor Jesica Ferry
Associate Editor Susan Fager

ISASI Forum (ISSN 1088-8128) is published quarterly by the International Society of Air Safety Investigators. Opinions expressed by authors do not necessarily represent official ISASI position or policy.

Editorial Offices: Park Center, 107 East Holly Avenue, Suite 11, Sterling, VA 20164-5405. Telephone 703-430-9668. Fax 703-430-4970. E-mail address isasi@erols.com; for editor, espmart@comcast.net. Internet website: www.isasi.org. *ISASI Forum* is not responsible for unsolicited manuscripts, photographs, or other materials. Unslicited materials will be returned only if submitted with a self-addressed, stamped envelope. *ISASI Forum* reserves the right to reject, delete, summarize, or edit for space considerations any submitted article. To facilitate editorial production processes, American English spelling of words will be used.

Publisher's Editorial Profile: *ISASI Forum* is printed in the United States and published for professional air safety investigators who are members of the International Society of Air Safety Investigators. Editorial content emphasizes accident investigation findings, investigative techniques and experiences, regulatory issues, industry accident prevention developments, and ISASI and member involvement and information.

Subscriptions: A subscription to members is provided as a portion of dues. Rate for nonmembers (Domestic and Canada) is US$28; Rate for nonmember international is US$30. Rate for all libraries and schools US$24. For subscription information, call 703-430-9668. Additional or replacement *ISASI Forum* issues: Domestic and Canada US$4; international member US$4; domestic and Canada nonmember US$6; international nonmember US$8.

AIR SAFETY INVESTIGATORS

INCORPORATED AUGUST 31, 1964

2013 Was an Invigorating Year

By Frank Del Gandio, President

As we start a new year, it's time to reflect on our accomplishments over the past year. Our membership totals 1,413, and we have 129 corporate members. The good news is that we continue to sign up new members; but unfortunately, we continue to lose about the same number due to many reasons: member retirements, financial problems, and death. Also, some members may just overlook renewing their membership. So let me remind you that ISASI dues for 2014 were payable no later than January 31. If payment slipped your mind, please take pen in hand and correct that now. Or you can call our office manager, Ann Schull, at 703-430-9668 or e-mail isasi@erols.com to make expedited payment arrangements. Members who fail to renew, for whatever reason, are placed in an "inactive" status, and membership benefits are suspended, as is delivery of *ISASI Forum*.

The year 2013 has been a busy one for the society. We have experienced growth as an international organization with the addition of the two new societies. The Middle East North Africa Society of Air Safety Investigators (MENASASI) and the Korea Society of Air Safety Investigators (KSASI) both submitted petitions of affiliation with ISASI. Both were accepted by the International Council.

In addition, on May 29, 2013, the International Civil Aviation Organization (ICAO) Council, in session, and while dealing with ICAO relations with the United Nations, specialized agencies, and other international organizations, "agreed that the International Society of Air Safety Investigators (ISASI)…should be included in the list of international organizations that may be invited to attend suitable ICAO meetings as observers." This long-sought status has become a reality. ISASI is now a full-time observer organization. As such, ISASI is able to partake in the deliberations of the ICAO Air Navigation Commission, particularly those involving matters related to Annex 13—aircraft accident and incident investigation to the Chicago Convention. Your council quickly formed an ICAO Working Group (WG). Ron Schleede will serve as our "point of contact," the official ICAO term for the contact position. Other WG members are Caj Frostell and Richard Stone. Bob MacIntosh is the alternate.

Similarly, we have broadened our reach in some meaningful areas. Out student mentoring program, which began in 2012 and is directed by Anthony Brickhouse, has made great strides. At last count, 27 members have volunteered to be mentors to an equal number of students. This program is growing at an appreciable pace. If you would to become a mentor, send an e-mail to Anthony (anthony.brickhouse@erau.edu). Our ISASI memorial scholarship program continues its successes. For 2013, the Scholarship Committee of Richard Stone and Ron Schleede selected four students to each receive a $2,000 award. It has been through the generous contributions of society members, chapters, and individual societies that award funds remain sufficient to support this program. If you wish to contribute, see our website, www.isasi.org, for more information.

ISASI's Reachout workshop program conducted two workshops this past year, one in Spain and one in Korea, the society's 43rd workshop program. Our member communications program has expanded and been updated. We have developed an entirely new and very user friendly website. Thanks to Dick Stone and Alicia Story for their hard work on this project.

In addition, we have entered the electronic age with the creation of the *ISASI Web RoundUp News*, edited by Marty Martinez, and an electronic newsletter, edited by Gary DiNunno, distributed by e-mail. Tentatively titled *ISASI UPDATE*, we are seeking a permanent title for it from you, our members. Submit your suggested name to Gary at dinunno@verizon.net.

Two very deserving ISASI programs are, in my opinion, underused. The first is our premier peer-recognition Jerome F. Lederer Award program. Of the many long-term safety advocates in our society and within the industry, we receive relatively few nominations for this award. The nomination process is uncomplicated and can be found on our website. Won't you give some thought to nominating a person who you feel has given so much of his or her talent to making the skies safer?

The second underused program is our own Fellow Membership status. This elite senior membership only requires you to submit an application of consideration to ISASI's Board of Fellows. Again, the details of submission, the criteria, and the application are available on our website.

Our annual conference on air accident investigation continues to be a star performer. Last year, 288 delegates from 34 countries attended ISASI 2013 in Vancouver, B.C., Canada. It was hosted by the Canadian Society, and Barbara Dunn served as program chairperson. This coming October 13–16, the seminar will be hosted by the Australian Society and will be held in Adelaide, Australia. Program chair is Lindsay Naylor.

We experienced a few personnel changes during the year. Robert MacIntosh has assumed the position of ISASI

(Continued on page 30)

Korea's Structure for Aviati

By Cho Taehwan, Chairman, Korea Aviation and Railway Accident Investigation Board (KARAIB)

(Adapted from Chairman Cho's keynote address presented by Dr. Jenny Yoo to the delegates of ISASI's 44th annual international conference on air safety accident investigation on Aug. 21, 2013, in Vancouver, B.C., Canada.—Editor)

Good morning. Chairman Dr. Cho sends his sincere regrets that he could not attend as scheduled. He also sends his strong support to ISASI for the success of this 44th annual seminar.

Chairman Dr. Cho specifically asked that I express his thanks and the thanks of the entire aviation industry in Korea to ISASI for its support in connection with the ISASI Reachout workshop conducted in April 2013. Fifty-two participants from nine states in the Asia-Pacific region attended, along with several student observers. The responses to attend were so overwhelming that many people who wanted to attend could not be accommodated. The instructors were most dedicated and selfless: Ron Schleede, Toby Carroll, and Curt Lewis. I am commenting on this because we all know that the instructors do not get paid for conducting an ISASI Reachout workshop, as it is purely voluntary work to enhance aviation safety in that particular region.

The intent of this address is to provide you a brief overview of the government structure for aviation safety in Korea. All the aviation-safety–related agencies are affiliated with the Ministry of Land, Infrastructure, and Transport (MLIT), which oversees transportation safety in Korea. The aviation regulatory body is the Civil Aviation Office, and it is located in the government complex in Sejong City, which is situated in the central part of South Korea. You may be unfamiliar with the city name Sejong, as it is a city newly created and intentionally planned for government administration, such as Washington, D.C., or Canberra in Australia.

Figure 2. A/C Accident/Incident Investigations

1.1, 2008~5.31, 2013

Classification	Type	2008	2009	2010	2011	2012	2013	Total
Accidents	Airplane	3	5	3	2(1)	3*(3)	2(2)	**18(7)**
	Rotoarcraft	1	2	2	5(1)	2(2)	1(1)	**13(4)**
	Light A/C	-	1	2	5	2(1)	-	**10(1)**
	Ultra Light A/C	2	5	-	2	2(2)	1(1)	**12(3)**
Serious Incident	Airplane	7	7	12	3(1)	9**(8)	1(1)	**39(10)**
	Rotoarcraft	1	3	2	-	-	-	**6**
Total		**14**	**23**	**21**	**17(3)**	**18(16)**	**5(5)**	**98(25)**

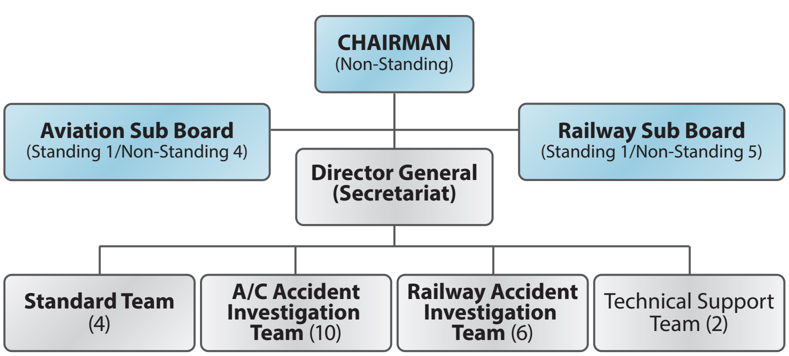
* Included 2 ROK Registered A/C occurred in foreign countries
** Included 2 foreign A/C serious incidents occurred in ROK territory
( ) Under Investigation

While KARAIB is affiliated with MLIT, it is an independent accident and incident investigation board for aviation and the railroad in Korea. The corresponding law clearly prescribes that the minister, other than for administrative purposes, shall not interfere with investigation activities conducted by the board.

As for the organization of KARAIB (see Figure 1), we have a chairman (nonstanding); two sub-boards of aviation and railway, respectively; and a secretariat led by a director general. Under his leadership, there are four teams: standard, aircraft accident investigation, railway accident investigation, and technical support. In addition, there are 17 advisors by area of expertise: legal affairs, technical engineering, forensic science, languages, fire and explosives, etc. The office is also located in Sejong City while the flight recorder/metallurgy lab and wreckage hangar are within the area of the Gimpo International Airport in Seoul.

History shows that the start of KARAIB was feeble, as they say, with only two aircraft accident investigation officers appointed in 1990. These officers were tasked with other main duties if there was no aviation accident to investigate. Then in 2001, we were rated a Category 2 as the result of the FAA IASA. It was a really difficult time for the Korea aviation community, but it was a blessing in disguise because the government aviation structure was rapidly expanded shortly after the rating. Through this opportunity, in 2002 the Korea Aviation Accident Investigation Board was established with seven board members and 17 investigators. And in 2006, the railway sector was integrated with the aviation board. Consequently, the Korea Aviation and Railway

Figure 1. KARAIB Organization Chart



*Advisors: 17 (Legal Affairs, Technical Engineering, Forensic Science, Languages, Fire & Explosives, etc.)

www.araib.go.kr, TEL 82-044-201-5422, FAX 82-44-201-5698
Government Complex-Sejong, Sejong City
Flight Recorder/ Metallurgy Lab, Wrechage Hanger: Gimpo Int'l Airport

on Safety

Figure 3. Casual Factors

1.1, 2008~5.31, 2013

Classification	Total (%)	Civil A/C	State Agency, etc A/C			Police	
			Forest SVC	119 (NEMA)	National Park SVC	Land Police	Coast Gaurd
Accidents	43(100)	26	- -	3	0	0	3
Human Factors	28(65)	7	7	1	0	0	3
Maintenance	5(12)	2	2	1	0	0	0
Weather	2(5)	1	1	1	0	0	0
Other	2(5)	2	0	0	0	0	0
Remarks	U/I 6	U/I 4	U/I 1	U/I 1			

- U/I: Under Investigation
- Included in Investigation Category in 2007 (increasing number of A/C engaged in high level of difficulty missions and high operation rate, 10<state agency 40)

Accident Investigation Board emerged with 12 board members and 26 investigators.

During the past five and a half years, the board's investigation activities have included 18 accidents to airplanes (seven cases are still under investigation), 13 to rotorcraft (four are under investigation), and 39 serious incidents to airplanes (10 are under investigation). See Figure 2.

A special feature of the board's investigation activities involves state agency aircraft. We have an increasing number of them, and their increasing accident rate has become a public issue. With this background, the board has since 2007 included the state agency aircraft accidents in its investigation scope. In terms of causal factors, as in civil aircraft accidents elsewhere in the world, human factors has been the primary factor. See Figure 3.

Shown in Figure 4 are some civil accident aircraft investigation photos.

A special feature of the board's investigation activities involves state agency aircraft. We have an increasing number of them, and their increasing accident rate has become a public issue. With this background, the board has since 2007 included the state agency aircraft accidents in its investigation scope. In terms of causal factors, as in civil aircraft accidents elsewhere in the world, human factors has been the primary factor. See Figure 3.

Shown in Figure 4 are some civil accident aircraft investigation photos.

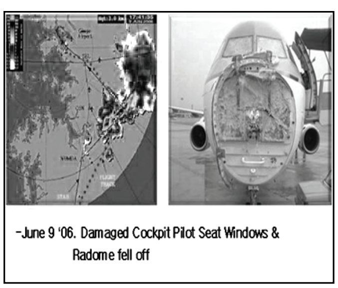
Concerning the effort to promote investigation quality, I need to note the ICAO USOAP conducted for Korea in 2000 in association with Annexes 1, 6, 8 to the Convention on International Civil Aviation. Then our compliance rate was low—below 80%; and as stated earlier, soon after in 2001 we were rated a Category 2 by the FAA. Within about a four-year time period, until the next comprehensive ICAO USOAP in 2005, the will and extensive efforts of both the government sector and air carriers to get Korean aviation safety on the right track were evident in every area that needed to be fixed.

At the same time, aviation safety professionals recognized worldwide for their aviation safety expertise were willing to guide and help. Ron Schleede is one of those who has been assisting, unsparingly sharing his knowledge and experiences from the 007 accident, Guam accident, Gimhae accident, ICAO USOAP, ISASI Reachout workshop, etc. Eventually in 2005, the result of the ICAO USOAP showed that our compliance rate was 98.82% with almost no findings, which was the best outcome among 191 ICAO contracting states.

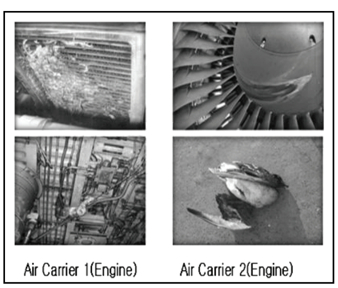
Having seen these changes, I firmly believe that the aviation safety community is one, borderless; and in this aspect this ISASI annual seminar is such a valuable means to get us united as one.

Before the ISASI Reachout workshop held in April, the Korea–ISASI relationship was two corporate members: Air Force and KARAIB, plus one individual member. On the last day of the workshop, 40 some people signed application forms. Following the success of the workshop, we had a Korea Society of Air Safety Investigators formation meeting. It was held in June, and officers were elected: Dr. Cho, president; the aircraft accident team director Jungkwen Park, vice president; and Dr. Jenny Yoo, secretary and treasurer [Affiliation with ISASI occurred on Aug. 18, 2013, by ISASI International Council action]. I hope that you will continuously encourage and support us, and we will be able to show more remarkable progress at the next annual seminar. ◆

Figure 4. Civil Accident Aircraft Investigation Photos

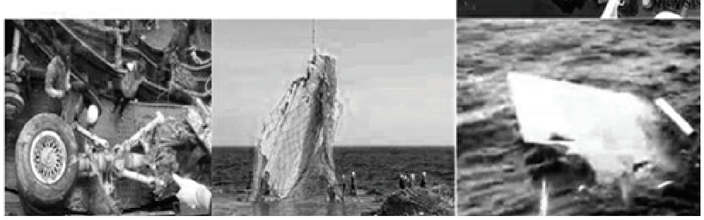


Inflight Fire



Bird Strike

- July 2011, B747-400F
- Crashed into Water
- Fatality: 2 flight crew members
- Under Investigation



Inflight Fire

Safety Data: The Agony And the Ecstasy of Their Use

How accurate can data analysis get in predicting accidents and incidents? How much emphasis of limited investigative resources should be placed on data mining and analysis? Is this just a panacea or a legitimate basket in which we should place all of our eggs?

By Jeff Guzzetti (AO3317)

(Adapted with permission from the author's technical paper entitled The Agony and the Ecstasy of Utilizing Safety Data for Modern Accident Prevention and Investigation *presented at the ISASI 2013 seminar held in Vancouver, B.C., Canada, on Aug. 19–22, 2013, that carried the theme "Preparing the Next Generation of Investigators." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org under the tag "ISASI 2013 Technical Papers."—Editor)*

With the advent of flight data recording technology, new requirements for Safety Management Systems (SMS), and the proliferation of voluntary safety reporting, the business of accident/incident prevention and investigation is being transformed from traditional crusty "tinkickers," who dig out and disseminate lessons learned from crash sites, to a new generation of IT-savvy safety professionals who mine electronic data. But how effective is this transformational approach? How accurate can data analysis get in predicting accidents and incidents? How much emphasis of our limited investigative resources should be placed on data mining and analysis? Is this just a panacea or a legitimate basket in which we should place all of our eggs?

On Nov. 27, 2007, during the kick-off of the 4th Annual International Aviation Safety Forum hosted by the Federal Aviation Administration (FAA) in Washington, D.C., Robert A. Sturgell, the FAA administrator at that time, said: "Aviation no longer is in the business of combing through ashes and wreckage to find answers. SMS will give us the intelligence we need before the problem reaches the headlines. When it comes to risks, the low-hanging fruit is long gone. SMS uses hard data to point us in the direction we need to go. We don't have to wait for something bad to happen."

Was this an accurate view six years ago? Is it accurate today? A solid argument can be made that it is not. Tinkicking will always be needed as a major aspect of preventing future accidents, and there is still plenty of low-hanging fruit to pick. This is especially true for the general aviation community, which has not yet undergone the same massive data-driven programs of the commercial airline industry and must still rely heavily on traditional investigative methods.

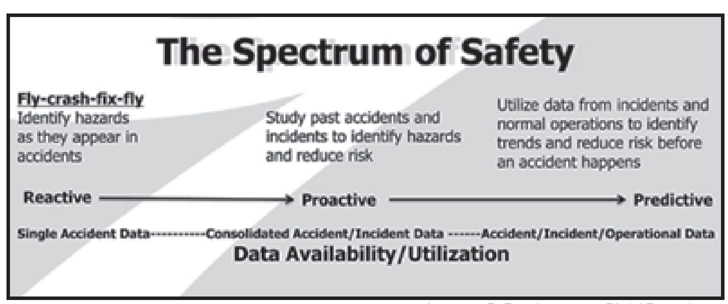
But that's not to say that data analysis is a wasted effort—quite the contrary. In fact, data mining has played a key role in decreasing the airline accident rate over the past two decades. More recently, it has helped to quickly solve particularly complex incidents and accidents, such as the Boeing 777 dual-engine roll back and subsequent short landing to a London runway on Jan. 17, 2008. However, data analysis has not yet been able to truly "predict" accidents, and it will never replace accident investigation. We should not be lulled into diverting the bulk of our limited resources to mining data instead of following the evidence found at the crash site while using human intuition to solve accidents and prevent future ones.

Defining expectations: proactive vs. predictive

To properly describe and account for the agonies and the ecstasies of data analysis in utilizing safety data for modern accident prevention and investigation, some terms must be established to put things into perspective. Jim Burin of the Flight Safety Foundation effectively laid out a simple scheme in a paper he presented at the 2012 ISASI seminar entitled *Being Predictive in a Reactive World* in which he described the differences between being "reactive," "proactive," and "predictive."

In the early days of aircraft accident investigation, the industry was mostly reactive—waiting until an accident happens and then addressing the risks. As air safety methodologies matured, the industry became increasingly proactive—doing something before an accident happens by using data and lessons learned. Now with the advent of massive amounts of recorded data and voluntary reports, the industry is attempting to be more predictive—doing something based on potential risk to avert an accident that has not happened (yet). Figure 1 depicts a scale of how these definitions might be viewed.

Figure 1. The Spectrum of Safety



Source: J. Burin, 2013 ISASI seminar

But predictive is a term we should use with great care. Does it mean that the data analysis is so good that a team of air safety prevention specialists can be automatically alerted to stop a taxiing aircraft from taking off? This scenario is reminiscent of Steven Spielberg's futurist film *Minority Report* in which Tom Cruise rappels down to stop an event that hasn't happened yet, but was foretold through technological means. Or does predictive mean that we are simply identifying a major risk area that will likely result in an accident within a specific segment of aviation at an unknown time and place in the near future? In this latter case, being predictive is achievable, albeit with significant challenges. We must be cautious not to oversell the benefits of data analysis.

FAA's ASIAS program—a new hope

Perhaps the most hopeful proactive scheme for aviation accidents, but not yet predictive, is the FAA's Aviation Safety Information Analysis and Sharing (ASIAS) system. Implemented in 2007, ASIAS collects and analyzes data from multiple databases to proactively identify and address risks that may lead to accidents. The ASIAS program was self-initiated by FAA without regulatory or congressional prompting. It is a collaborative industry-government information-sharing and analysis system that combines, analyzes, and disseminates aviation safety data and report products. ASIAS accommodates air carriers' desires to benchmark their safety efforts against industry standards, and it allows government analysis and some sharing of data. The system is fed by a wide variety of data sources from both public and protected proprietary aviation data (see Figure 2). Publicly available data include information from many sources such as the NTSB Accident and Incident Reports database and the FAA's Service Difficulty Reports database. Proprietary and/or confidential sources include data from aircraft operators, including Flight Operations Quality Assurance (FOQA) data extracted from aircraft recorders, and voluntary safety reports such as the Aviation Safety Action Program (ASAP) submitted by flight crews. These data represent millions of flight data records and textual reports, according to an FAA fact sheet from June 30, 2013.

Figure 2. ASIAS Data Sources

Source: The FAA

Interactions between the FAA and the aviation industry range from analyzing ASIAS data to identifying and recommending risk mitigations. The 20-member ASIAS Executive Board assigns teams to conduct studies, receives ASIAS study recommendations, approves all analyses, and sends findings

***Jeff Guzzetti** began his 30-year aviation safety career as an engineer for the U.S. FAA and later held positions in systems safety and accident investigation for the U.S. Department of the Navy and the Cessna Aircraft Company. He joined the U.S. NTSB in 1992 and worked in the NTSB Office of Aviation Safety for 17 years as a field investigator, aerospace engineer, major team investigator-in-charge, and finally as the deputy director for regional operations. In August 2010, he was appointed as the assistant inspector general for aviation audits at the U.S. Department of Transportation Office of Inspector General. He holds a commercial pilot certificate with ratings in multiengine instrument airplanes.*

and recommendations to the Commercial Aviation Safety Team (CAST) for a joint decision on whether action is needed by industry or government. CAST has proven to be a very effective proactive safety effort in its own right. It is a U.S. government–aviation industry partnership, founded in 1998, that has developed an integrated, data-driven strategy to reduce the nation's commercial aviation fatality rate by analyzing causes of past accidents, identifying areas where changes may have prevented them, implementing promising safety enhancements, and measuring their results. CAST's goal to reduce the commercial airline fatal accident rate by 80% in 10 years has now been achieved—not with sweeping laws or with any single "home run" but with a series of 76 separate "singles," seemingly mundane, low–cost "safety enhancements," wrote Alan Levin in an article appearing in *Bloomberg Businessweek*, on Jan. 26, 2012. Seven of these enhancements resulted from ASIAS. CAST's impact is an example of an "ecstasy" associated with data collection and analysis. CAST's new goal is to reduce the airline fatal accident rate another 50% by 2025 as compared to the 2010 rate.

According to a recently released audit report on ASIAS by the U.S. Department of Transportation's Office of Inspector General (DOT OIG), the FAA has made significant progress with implementing ASIAS. For example, 44 commercial airlines that represent 95% of all Part 121 operations in the U.S. are now providing key confidential data from voluntary safety reporting programs to ASIAS, up from only 11 airlines in 2007. As of June 2012, ASIAS had access to about 110,000 ASAP reports as well as the content of 8.1 million flights of FOQA data. Additionally, the number of data and information sources has grown to 131.

However, ASIAS is not yet truly predictive. For example, one of the seven "directed studies" from ASIAS addressed the issue of pilots' taking off from the wrong runway. This 2007 study, *Runway Aviation Safety Information Analysis and Sharing: Wrong Runway Departures*, was initiated shortly after the tragic wrong runway takeoff of Comair Flight 5191 in Lexington, Kentucky, in August 2006. The study simply validated what the news media had already reported only a few days after the accident—that wrong runway takeoffs were common errors. With access to public information from NTSB, FAA, and NASA databases, the reporters found hundreds of cases of pilots trying to take off or land on improper runways since the 1980s. Some folks within the FAA and ASIAS circles asserted that if ASIAS had been fully up and running prior to Lexington, then the crash would have been prevented. It is easy to assert this after an accident, but "hindsight is 20/20," as they say. The hard part or "agony" regarding safety data analysis is to identify and prioritize the information needed from a vast sea of data. How would anyone have known that the next fatal accident would involve a wrong runway takeoff with all of the subtleties of the specific cause and factors that led to Lexington?

The evolution of ASIAS to a more predictive tool, as envisioned by the FAA, is still several years away. This is due to the challenges, or agonies, associated with deploying technologically advanced and complex capabilities such as

- querying multiple databases with a single-search directive for improved, quicker data searches,
- conducting automated trend/anomaly detection of vulnerabilities (e.g., hazards such as loss of separation between aircraft) based upon digital data,
- developing tools to uncover hard-to-find (not predefined) subgroups of flights with higher rates of safety precursor events, and
- fully integrating pilot–controller voice communications data utilizing data fusion capabilities into the ASIAS data set.

After these capabilities are deployed, ASIAS will be a much more powerful proactive tool for air safety professionals. However, it may still never be able to truly predict specifically when and where the next accident will occur.

Other agonies that exist with ASIAS involve challenges that are much more near-term. For example, the U.S. Government Accountability Office in a 2012 audit report (GAO Report-12-660T) noted that the FAA is struggling with nonstandardized data collection practices, incomplete or inaccurate information, and difficulties with processing data in a uniform manner as a result of deficiencies from the data that ASIAS receives from airline safety reporting programs.

Further, because the FAA's initial focus for ASIAS was on safety data from commercial airline operations, ASIAS does not yet incorporate substantive data from other segments of the industry, such as general aviation operations. To its credit, the FAA is following a phased expansion plan to include other parts of the aviation community in an effort to further enhance the safety benefits that ASIAS could provide to all aviation sectors.

Moreover, access to the full capabilities of ASIAS has been limited. The data are closely guarded by the ASIAS Executive Board, and the results of these analyses are shared only with ASIAS participants, and only through high-level executive summary reports and industry information-sharing venues. Other aviation communities may also share in these analyses, but only when approved by the ASIAS Executive Board. In fact, the FAA does not yet allow its own inspectors access to ASIAS data from voluntary safety programs (i.e., FOQA, ASAP) despite the fact that these data could provide them visibility into safety issues experienced by other similar air carriers and aircraft fleets, resulting in more focused and effective oversight. The FAA has reported that it plans to expand access to its inspectors, but the effort has been slow—apparently due to concerns that air carriers will be reluctant to continue volunteering information for fear of reprisal from their regulators. However, these fears are likely unfounded, as the data can be sanitized and aggregated.

Even the NTSB, a nonregulatory independent body, had to work hard for nearly two years to convince the FAA and stakeholders to allow it to obtain specific ASIAS data in the wake of an accident. A written agreement was finally struck this past November [2012] allowing the NTSB to initiate written requests for ASIAS information related to aircraft accidents involving U.S. air carriers that occur in the United States. The NTSB has agreed it will not publicly disclose ASIAS information that it receives via this process unless the ASIAS Executive Board agrees. The data are to be de-identified and aggregated. The agreement also does not allow any of the parties to use aggregate FOQA, ASAP, ATSAP, or other nonpublicly available data to measure an individual data contributor's performance or safety.

The justification behind this "close-hold" safety data philosophy is to ensure that airlines and other reporting entities remain confident that their proprietary data will be adequately protected and not come back to support punitive actions against them. However, a reasonable balance must be found between protecting the data to prevent a "chilling effect" while allowing more safety professionals greater access as a force multiplier for safety analyses and, ultimately, safety improvements.

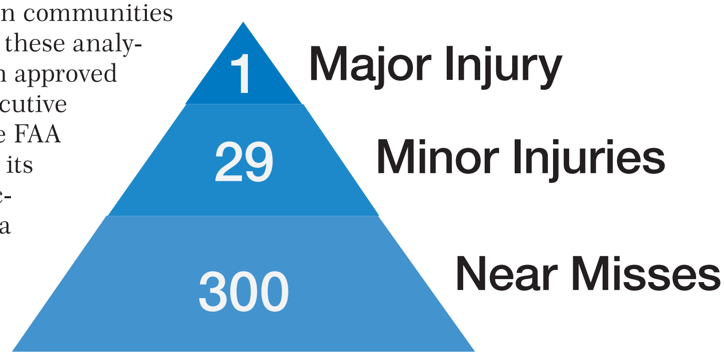


Figure 3. The Heinrich 300-29-1 Model

Heinrich's triangle—turned on its side

Another caution for the next generation of investigators and aviation professionals is to be mindful of not becoming overly obsessed with data from previous incidents that may portend an accident with similar characteristics. The "Heinrich Pyramid" scheme, a model in which safety events of varying severity could be represented in a pyramid (see Figure 3), has been a stalwart in the field of safety for decades. In 1931, American industrial engineer Herbert W. Heinrich published an empirical finding that for every accident in a workplace that causes a major injury, there are 29 accidents that cause minor injuries and 300 accidents that cause no injuries. The reasoning behind this scheme is simple: many accidents share common root causes; and therefore, addressing more commonplace accidents that cause no injuries can prevent accidents that cause injuries. This finding is well known in our profession, especially within the context of SMS, in which one of the four major SMS components is "data collection and analysis," noted Robert L. Sumwalt, NTSB board member, in a presentation.

However, Heinrich's Law has proven to be invalid in several types of aviation operations. According to research conducted [in 2012] by the staff at the Imperial College London's Transport Risk Management Center, many accidents have occurred with "sudden failures" that had nothing to do with any previous trend of incidents.

One example cited in F. Nascimento's *Investigating the Truth of Heinrich's Pyramid in Offshore Helicopter Transportation* was operations involving helicopters that service the oil and gas industry. For the most part, this industry is very safety conscious, due to its competitive nature and the arduous environment in which it operates. The industry has driven the safety requirements for helicopters that operate worldwide, especially in the North Sea, where operators must abide by a British requirement for Mandatory Occurrence Reporting (MOR) to meet the critical element of the ICAO-mandated SMS program. The researchers examined the correlation with occurrence reports and accidents, and the results were startling. Between 1997 and 2010, there were 10 offshore helicopter accidents, and 789 incidents reported under MOR. Each accident was analyzed, along with the previous two years of MOR data. The conclusion of the research revealed that the MOR data analysis could not have predicted the accident that preceded them.

Similar research by S. Mitchell in *Helicopter Safety Reporting Culture* was cited involving a review of British MOR data for all types of helicopter operations from 1995 through 2004. In one study, the researcher identified that while only 10% of the filed reports corresponded to private flights, such operations sustained 47% of all helicopter accidents in the same period. It was also noted that human factors issues were only causal in 17% of the reported occurrences, but human factors were attributed to 76% of the accidents. The opposite was found in regard to airworthiness failures, which corresponded to 98% of the MORs but only 16% of the accidents.

This demonstrates that our new generation of accident investigators should take into consideration the specific types of flight operations involved in the accident and to identify any and all complex operational variables and human factors. The more complex, the less likely that Heinrich's pyramid should be applied. These accident types are characterized by a multiple, rare, and nonlinear combination of factors that are often not evident in routine incidents.

The needs and limitations of data

The aforementioned British researchers, as well as other research conducted by the MITRE Corporation and others, also discovered other important aspects or agonies associated with the usefulness of data analysis. For example,

- In one research study conducted by the British Royal Air Force (RAF), a bias was identified toward the reporting of technical issues. From the more than 4,800 RAF occurrence entries of 2007, only 65 were related to human factors.
- Data that are overly general will not provide many interesting results. MITRE Corporation researchers noted that while the NASA Aviation Safety Reporting System (ASRS) has been extensively de-identified to protect pilots, this de-identification results in the loss of the details needed to find subtle patterns.
- Varying data-collection practices and taxonomies prohibit the melding of data from many different sources.
- Information embedded in report narratives is very difficult to glean and categorize.
- Finding associations and distribution patterns in data is difficult because of having too many results returned by the tools. This leaves the analyst with the task of going through a large amount of findings and separating the ones that are relevant, unusual, surprising, or in any other way "interesting."

Recently published audit reports and testimony performed by the DOT OIG also pointed out additional agonies of utilizing safety data. For example, this past February [2013], the DOT OIG found that FAA's policies and procedures to identify and report on losses of separation between aircraft are limited by incomplete data and implementation challenges. It also found that the FAA lacks an accurate baseline of the actual total number of separation losses that occur. In addition, it found deficiencies with the use of a new air traffic operational error reports database, and it cited concerns regarding data collection and analysis due to inadequate staff, training, and familiarization. This is consistent with other previous research that indicates that informing data collectors about the needs of downstream data facilitates the generation of higher-quality data.

Another DOT OIG audit report (AV-2012-170) from August 2012 indicated that the FAA's wildlife strike database provided "an incomplete picture of the total number and severity of wildlife strikes that occur," hindering the effectiveness of the FAA's efforts to mitigate the increasing hazards of bird strikes. The auditors cited an FAA-contracted study in 2009 that concluded only 39% of actual wildlife strikes were reported and as many as 36% of the events involving wildlife in the FAA's Accident/Incident Data System were not captured in its wildlife strike database. The auditors also found that, because strike reporting is voluntary, airports varied in how frequently they chose to report strikes to the FAA. For instance, they found that at one large airport, 90% of the airport's recorded strikes were reported in the FAA's strike database while another medium-sized airport reported only 11% of its strikes.

Figure 4. Boeing 777-236 ER Lands Short of Runway at Heathrow Airport

Data analysis to help solve accidents

Because of the proliferation of safety data, the next generation of investigators can now turn to data mining and analysis to assist them in solving complex accidents. This ecstasy was demonstrated with the investigation of an accident that occurred on Jan. 17, 2008, when a Boeing 777-236ER landed short of the runway during approach to London's Heathrow Airport from Beijing, China. At 720 feet above the ground, the right engine stopped responding to autothrottle commands for increased power and instead "rolled back" on power. This was followed by a roll back of the left engine seven seconds later, resulting in a loss of airspeed and the aircraft touching down some 330 meters short of the runway. The physical evidence at the crash site, and even the waterfall of parameters from the flight data recorder, did not yield obvious clues. So the British AAIB underwent a data-mining exercise (see figure 4).

The intent of this data-mining activity was to identify any parameters or a combination of parameters that were unique to the accident flight. Initial analysis of the accident flight identified that certain features were unusual or unique when compared to a small number of flights having operated on the same route and under similar atmospheric conditions. However, it was difficult to place a statistical significance on these findings alone due to the small sample size. Unencumbered with any existing data-access problems from British rules, the AAIB obtained and analyzed an additional 175,000 flights of Boeing 777s, and the agency identified that the accident flight was unique among 35,000 Rolls-Royce–powered flights in having a combination of the lowest cruise fuel flow, combined with the highest fuel flow during approach while at the lowest temperature on approach. Just two flights from 142,000 Pratt & Whitney-powered aircraft flights had these features.

As a result of the AAIB's data-collection and analysis efforts, the investigation identified that the reduction in thrust was due to restricted fuel flow to both engines. It was determined that this restriction occurred at the engines' fuel oil heat exchanger. Accreted ice from within the fuel system released, causing a restriction to the engine fuel flow at the face of the exchange on both of the engines. Ice had formed within the fuel system, from water that occurred naturally in the fuel, while the aircraft operated with low fuel flows over a long period and the localized fuel temperatures were in a specific area. The AAIB issued 18 safety recommendations from the investigation to enhance the certification and operations of transport aircraft.

According to the AAIB report(G-YMMM EW/C2008/01/01), the data-mining process "was largely complementary to the laboratory testing that had been ongoing during the course of the investigation, with features identified from the data mining being incorporated into laboratory tests and, similarly, laboratory results being applied to the data analysis."

Safety Data Use for Accident Investigation and Prevention

The Ecstasy....

- CAST and its impact on reducing the fatal commercial airline accident rate by 83%.
- Solving the Boeing 777 engine roll back accident at London Heathrow airport.
- Ability to accurately measure safety improvements.
- Better targeting of proactive risk mitigation strategies.

The Agony....

- Need for more staff and resources to analyze data.
- Poor data quality, consistency, and distribution.
- Knowing what to look for and how to sort safety data.
- Becoming too fixated with data analysis and not using human experience and intuition.
- Incident data may not be accurate indicators for accidents.
- Safety data are too closely held.
- Convincing people to take action, even after the case is proven.

Figure 5. Safety Data Use for Accident Investigation and Prevention

Conclusion

There is no doubt that more safety data, and the analysis of that data, lead to better risk management in aviation or any other endeavor. Data analysis can also significantly aid in solving accidents. However, we must keep in mind the challenges (i.e., agonies) of this analysis, while recognizing the benefits obtained (i.e., ecstasies) with realistic expectations (see Figure 5).

Our next generation of accident investigators cannot substitute methodical post-accident tinkicking efforts with sitting in front of a computer —mining for data—in a comfortable office. A balance of both will be needed. Accident investigations bring together diverse groups of experts in a focused and structured environment. This synergy of human experience and motivation cannot be matched by a database. Not yet, anyway. Regardless, even with all the evidence—whether from the crash site or a supercomputer—perhaps the most challenging agony is convincing the decision-makers to take the action needed to prevent the next accident. ◆

The views expressed in this paper do not necessarily represent the views of the United States, the U.S. Department of Transportation (DOT), the DOT's Office of Inspector General, or any other federal agency.

Using Brain Power to Prevent the Next Accident

By Thomas Fakoussa

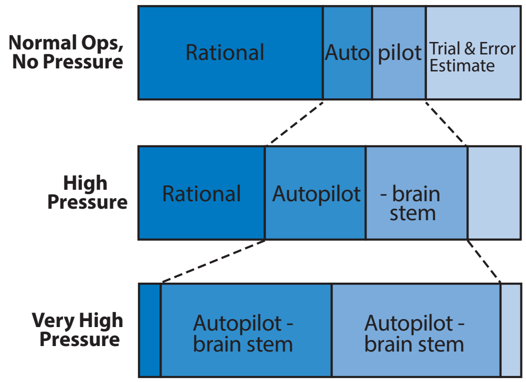
How does a human brain react to new unfamiliar and unexpected situations? The human brain needs a balance of feelings and rationality to be able to operate on the basis of conscious behavior.

(Adapted with permission from the author's paper entitled Investigating Accidents, but How to Prevent the Next? *presented at the ISASI 2013 seminar held in Vancouver, B.C., Canada, on Aug. 19–22, 2013, that carried the theme "Preparing the Next Generation of Investigators." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org under the tag "ISASI 2013 Technical Papers."—Editor)*

Traditional accident investigation concentrated on technical aspects. By investigating deeper and deeper into the technical aspects, more and more weak points were discovered, corrected, and/or improved. Thus, aviation became the safest means of transportation, and accident investigators saved thousands of lives.

With improvements to the technical side, human error became more evident, more outstanding. By investigators not being specialized in human factors, the outcome of the investigation did not address human error, and the investigation concluded with a "lack of situational awareness." Sometimes there are political reasons behind this, or the understandable desire to spare the people involved the "loss of face." But is this a means of preventing the next similar accident?

As long as we see the wrong reaction in similar situations (stall, unknown software problems called latent errors, undetected situations that would require quick decision-making), there must be an underlying base that these situations have in common. Lack of situational awareness is not the answer to it! A generally used and scientific definition of situational awareness as noted by Mica Endsley in 2000 is "Perception of the elements in the environment within a volume of time and space, the comprehension of their meanings, and the projections of their status in the near future." What we miss completely in that definition is the internal state of mind of the pilots. The knowledge of what a human brain does in these situations offers the solution for the future of accident investigation.



ATF - Awareness Tracking Fakiussa

From book of Gerd Spohd

The basic problem becomes clear if we start with the statement "A pilot can only react correctly to situations in which trained to react correctly!" This means that every time accidents happen, the pilots were not trained for that situation. Logic would than require that pilots should be trained for all possible situations they might encounter and not just on the motor, manual level. Achieving this without a change of training is not realistic.

So we have to concentrate on how to teach pilots to react mentally to new and untrained-for situations. And this should be stressed in the accident report. There are no individuals to be blamed, but the worldwide training system of pilots is at fault. The change in mental perception and mental data processing is not taken into account. And according to James Reason's Swiss Cheese model, this starts with ICAO, the FAA, and EASA and continues on to the level of national regulators, flight instructors, and type rating instructors.

There are no rules and guidelines about how to train a pilot in a modern cockpit compared to an old-fashioned cockpit, despite the fact pilots' data processing is completely different. There is not a single rule or even an idea about how to train (situational) awareness.

Let us answer the question: How does a human brain react to new unfamiliar and unexpected situations? I claim that the human brain needs a balance of feelings and rationality to be able to operate on the basis of conscious behavior.

Did Air Florida, Birgin Air, and Air France 447 crews show that conscious behavior? Does lack of situational awareness explain why the loss of consciousness took place? No and, therefore, it will happen again. Safety investigation means stop this development of nonrational reactions by pilots. To do this requires the accident investigator to stress the point called "pilot training" and expand it to the training of mental abilities in unexpected and unforeseeable situations.

Training worldwide misses the point of "what is" situational awareness, and how can it be taught. First we need to understand that situational awareness is only one aspect of much awareness. In the case of the Air Florida stall, the missing awareness was body awareness. If my arm reaches just 60% of the normal stretch for takeoff power, and I am not aware of that? Who trained me about body awareness?

Birgin Air, according to the report, got into a stall because the over-speed and stall warning came up nearly at the same time. Is this a normal and known situation for our brain? No, and therefore the brain switches into stress mode. This requires the body to direct all energy to the muscles and to withdraw it from the brain. Were the pilots trained for not getting into stress

(Continued on page 30)

Thomas Fakoussa *was born in Egypt and grew up in Germany where he started flying at the age of 17. He is an instructor pilot, ex-LH captain on the B-737, studied psychology all his life, and is now a consultant for more efficient brain training and achieving more safety awareness. He is also the author of* Looking for Awareness—In a Crash, *a book about how and why human error is "produced," and what can be done to avoid it.*

Any good investigator, especially the new tech-savvy, next generation one, needs to master all aspects of the job, both the technical and the personal…. Building and maintaining relationships make the job easier and more productive.

Building and Maintaining Relationships…. Lessons You Should Have Learned In Kindergarten

John Purvis has been in the aviation field for 57 years and for the last 31 has concentrated on accident investigation and airplane safety. The final 17 years of his long Boeing career were spent directing its commercial airplane investigation organization. Subsequently, he was an aviation safety consultant. John holds University of Washington degrees in mechanical and industrial engineering. In 2001 he was awarded ISASI's prestigious Jerome F. Lederer Award. He is an ISASI Fellow, AIAA Distinguished Lecturer (Ret.), professional engineer, and pilot. He is a docent at Seattle's Museum of Flight and a member of its Board of Trustees.

By John Purvis, ISASI Fellow

(Adapted with permission from the author's technical paper entitled Playground 101: Building and Maintaining Relationships…. Lessons You Should Have Learned in Kindergarten *presented at the ISASI 2013 seminar held in Vancouver, B.C., Canada, on Aug. 19–22, 2013, that carried the theme "Preparing the Next Generation of Investigators." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org under the tag "ISASI 2013 Technical Papers."—Editor)*

In our field of accident investigation, the importance of building relationships before you need them cannot be overstated. I believe relationships make our world turn. The benefits are so huge compared to the small costs of accomplishment that it seems negligent to avoid the task.

Major aircraft accidents suddenly bring together many diverse organizations and investigators who are strangers. These folks come together into a highly charged atmosphere where tensions, emotions, and loyalties are at a peak. Conflicts can easily arise. These conflicts could very well degrade the quality and timeliness of an investigation.

To avoid such conflicts and the possible loss of valuable investigative information, preplanning is imperative. The financial and manpower costs of building relationships by personal contacts, attending meetings, frequent e-mails, and the use of other communications media are relatively small. The effort and cost of holding contingency planning meetings with what could be essential players in an accident are minimal compared to the cost of friction and distrust that might exist without it.

Choosing the right people is critical

I believe that people who lead investigative teams should be selected on their ability to communicate and interface with others. These are the prime qualities. The necessary technical skills can be readily learned, assuming that the person selected has the proper education and background to begin with.

When I headed the Boeing team, I hired an average of about one new investigator each year. About 50% of my selection criteria was based on the interpersonal skills the candidates exhibited during their interviews. Many of the applicants I had known for years, so their abilities were well-established. Each was already a degreed engineer with a variety of background experiences within Boeing and with broad company knowledge. Walt Disney had an underlying ethic that applies here: In his view, "You hire the attitude. You can train the skill." Some of the major qualities to look for include

- technical expertise,
- experience,
- reputation,
- trust/ethics/credibility,
- communications, and

Author's Playground 101

Clearly, this is not a technical paper. I ceased writing those when I retired almost 15 years ago. This is really a collection of my observations, gathered over many years in the field of aviation safety.

It is a fact of life that when you retire and get older, the information you dispense gets softer. But that doesn't make it any less valuable. Any good investigator, especially the new tech-savvy, next generation one, needs to master all aspects of the job, both the technical and the personal. This paper concentrates on building and maintaining relationships to make your job easier and more productive.

Can anyone learn to build relationships? Yes, of course! Even the shy person or the introvert—even an engineer! I was the consummate shy and introverted kid, right from my first day of kindergarten. It was traumatic. I was left to fend for myself. My comfortable neighborhood was gone. Here were all these new faces.

There was nothing left to do except find my little seat and hunker down. Eventually I looked around, reached out, and began the mission of making friends. And in my case, I'm lucky to say some of those kindergarten friends are still close, people with whom I socialize today.

In those early years I learned to share, to participate, to reach out and to be a friend. These were invaluable learning experiences that have become the basis of my philosophy when working with officials and associates around the world. I was still shy and introverted, but eventually I outgrew my fears. Kindergarten was the beginning: my Playground 101.

- ability to work cooperatively in a group but still perform independently.

These qualities indicate that a candidate will be successful and ensure that he or she already has an appreciation for the importance and value of relationships.

However, more training and on-the-job effort are required. I paired each new investigator with an experienced investigator. On a first investigation, each served as a trainee to gain experience under the guidance of someone else. Eventually new investigators were sent to formal investigative instruction, which earned them a certificate.

Managers in other parts of the Boeing Company also selected new personnel based on their people skills, especially in sales where good relationships equate to survival. One very successful former vice president of sales, who was also a friend, highlighted relationships as a key factor in his success. I noted his remarks and tried to emulate his success. I believe the factors he named are equally important to any accident investigator because both operate in customer-centric environments, frequently in the international arena. In describing the importance of building relationships across multiple cultures and ethnic origins, he noted the following traits as being of vital importance:

- Develop and nurture relationships as much as possible,
- Truly like people,
- Enjoy pleasing people,
- Strive to be liked, and
- Be willing to help people.

He also focused on the importance of languages. You can't be expected to speak your customer's native language, but you should learn a few key words. Yes, no, please, and thank you are where you start, along with the daily greetings. This executive also emphasized the importance of having empathy with other cultures. Make the connection with their culture and, with the time you have, immerse yourself in it. Learn their history, appreciate their foods, and learn what is in vogue now. Get to know their current events and politics. That is, in general, be familiar with the culture. You also need to have a fundamental understanding of the political and economic environment in which your customer operates.

This sales executive's most important value was "to have common sense." That will take care of 90% of any situation. Always be you—as he said, who else is better qualified? Make sure always that you exhibit trust, credibility, and integrity. You cannot train for these—they must be inherent in the personality.

"Relationships & Trust are the 'beginning and end' of this business."

Another Boeing sales executive pointed out that at the heart of any sales campaign is the relationship you have with your customer: Strive to know your customers better than they know themselves. He further pointed out how important it was to be available to your customer 24/7and during visits to get to know everyone from the receptionist to the janitor to the CEO. Visits, he noted, should be spontaneous. Walk the hallways, learn the environment, and know the people. Relationships and trust are the "beginning and end" of this business.

While these are examples directed to sales folk, I believe they are equally important attributes for accident investigators. Obviously, there are major differences. Sales people have the luxury of time while investigators hit the ground running. As much as possible, you need to have the basics of these relationships well established ahead of time. Waiting until you need them is too late.

A tip: On business trips or when returning from an accident investigation, stop enroute to visit other government agencies, companies, and even your competitors. During my 17-year tenure leading the Boeing air safety group, I made more than 70 trips to Washington, D.C., and my staff made many more. On each trip, I visited the NTSB and tried to get to see the FAA accident investigators as well. It became a standing joke that the NTSB was going to set me up with an office, perhaps with a bed. I was there often enough that twice I launched myself on accidents from Washington, D.C., right alongside the NTSB team. That meant quickly buying some appropriate clothes and borrowing a camera and other gear.

The purpose of my trips to D.C. was to build relationships on all fronts. And not all of the 70 trips were stand-alone—many were made while going to and from other places in the world. This was a cost-effective way of doing business. And I believe it paid off.

Clearly, a single individual can't devote full time to making contacts. You don't need to do this alone. Your other investigative team employees may have already "been there and done that," and you can ride on their coattails and share in their knowledge. An example of this follows.

When Ron Schleede [ISASI vice president] and I taught investigation management together at SCSI, he would often relate the story of building some early relationships with the Chinese. While at the NTSB, Ron made an "ice-breaking" trip to Beijing in the late 1980s. That trip and a subsequent visit by high-level officials from China to the U.S. did not turn out to be as productive as everyone had hoped, at least not initially. However, the first Boeing aircraft were due to go into service in China soon, and Ron felt they needed to be prepared for the potential of an accident there.

Eventually, Ron managed to invite a delegation of "worker-level" investigators for a visit to the U.S. and the NTSB. That delegation included a person who was his counterpart in China—the chief of major investigations. During this visit, numerous discussions were held at the NTSB where the Chinese were able to meet their NTSB counterparts. They discussed contingencies should there be an accident involving a Chinese airline in the U.S. or a U.S. product in China. As part of the visit, Ron arranged to host a typical American barbecue at his home, and he invited the senior investigators from his office to join the party to meet the visiting Chinese delegation. These investigators-in-charge also serve as U.S.-accredited representatives on overseas accidents. It was an informal social event in his backyard.

Sometime afterwards, in November 1992, a China Southern Boeing 737 crashed near Guilin, China. The airframe and engine investigators arrived in Guilin ahead of the NTSB. The early arrivals were prevented from joining the investigation because the Chinese did not know them and were reluctant to give them access to the site or information. When the NTSB investigator/accredited representative landed in Guilin and exited the airplane, he was met by a smiling Chinese investigator-in-charge with whom he had spent time at Ron's barbecue. The entire NTSB team was welcomed and given access to the investigation.

Attending and taking part in accident investigator seminars produces great contacts.

Where and how to build relationships?

To me, the most effective and efficient way to build relationships in our field is to attend meetings such as ISASI seminars. In fact, I believe this is the single most important opportunity for you and your staff.

At ISASI annual seminars, you will find folks from all areas of the industry—everyone from investigators to government agencies to suppliers to large and small manufacturers, airlines, unions, consultants, and retirees. They come from all over the world. Such meetings save you considerable travel and afford you the opportunity to begin building some of those relationships that you probably should have started years ago.

These are the people you will be facing when the fire bell rings and you find yourself suddenly launched to an accident at some location or country completely unknown to you. You probably can't afford to visit all of these places ahead of time, so at such meetings is where you can interact with many of the people from these areas before the need arises.

While the technical content of an ISASI seminar is important to communicate new and useful information, it is during the breaks, lunches, and social events where the real work takes place, especially the work of building relationships. While we were planning ISASI 1995 held in Seattle, Washington, we purposely scheduled breaks and lunch sessions that were longer than usual for exactly that purpose.

Take advantage of these opportunities. Be present at all of them. Don't socialize just with the easy ones, the people you already know. Break out of your comfort zone and meet new folks, especially from areas outside your own country. Don't use this time to grab your cell phone or iPad and hide in a corner to conduct routine company business. That's a waste of this valuable, unique venue.

If your organization or company has sent more than one representative, use this opportunity to spread yourself out among the attendees to cover more ground. At the seminar itself, sit separately, scattered around the hall, not with your coworkers. You are there to build corporate relationships as well as personal ones.

Another way to meet people and build relationships is to become an active participant and partner in ISASI and its seminars. Run for office. Chair committees or working groups. Present papers. Lead panel discussions. Sponsor a seminar in your area. Provide regular financial support. Become active in your local chapter or society. Do whatever you are asked to do. Become a source, not a vacuum. Share your thoughts and ideas and, especially, listen to others. This is a good, cost-effective way to get to know others as well as to get others to learn about you and your organization.

There are many other similar opportunities each year around the world. Some examples include Flight Safety Foundation meetings, ALPA seminars, and chapter and society meetings outside your area or in other countries.

Another classic example of building relationships early involved an accident in Japan. In the early 1990s, Ron Schleede had built a very good relationship with one of the English-speaking JAAIC investigators. Occasionally they would speak on the phone and discuss contingencies for accidents occurring in their respective countries. There had been some concern in the U.S. about how flight crews might be treated in Japan if an accident occurred there.

During an ISASI seminar in the early 1990s, Ron introduced the safety manager from one of the concerned U.S. airlines and the head of their ALPA safety team to Ron's Japanese contact. Over lunch they discussed contingencies including how the flight crew would be handled should there be an accident in Japan. A few months later this same airline had an engine fall away during taxiing shortly after landing. There was a small fire but no injuries.

Because of the previously established relationship, no problems were encountered as a result of that event. The NTSB team of technical advisors, including the airline and the pilots' union, were welcomed to the investiga-

Breaks and social hours are ideal for interacting with peers.

tion and cooperation was excellent. (The NTSB did not send any investigators to Japan. However, at the request of the Japanese, they did work with the airline in the U.S. and their reports were forwarded to the JAAIC.) Several safety improvements resulted from these cooperative efforts.

To me, Ron is the consummate "relationship builder." If you want tips on the best way to do it, talk to him. He knows more people than anyone. Of course, from my own experience of working with Ron, not enough can be said about his positive influence in the 1985 JAL Flight 123 accident outside Tokyo where the 747's pressure bulkhead ruptured.

The NTSB investigator-in-charge initially assigned to that accident was not able to get his technical advisors (including me) involved in the accident and up to the site in the mountains. Ron's expertise was pressed into duty, and his quick appearance on site helped resolve these matters. From that point on, the U.S. technical advisors were a full part of the investigation.

Internal relationships

Another recollection: At Boeing my group investigated only the commercial airplane accidents. However, scattered around the company were other Boeing investigators who covered Long Beach products, military fighters, tankers, B-52s, helicopters, and such. Many of us had never met one another—initially we didn't even know some of the others existed. We thought there would be a benefit from bringing all these people together and talking about common problems and goals. Some company executives were against the meeting mainly because it was seen as a waste of time and money. However, we did hold the meeting, and it turned out to be a great success. It turned out that Boeing had 20 investigators at its facilities around the U.S. An NTSB board member was also in town at the time of the meeting and attended our pizza dinner afterwards. This proved the ultimate experience in building both internal and external relationships—all for the price of a pizza.

Lesson learned: Internal company relationships are just as important as the external ones that we have been discussing. In fact, they may be more important. You need to have good internal relationships to do your job well. Building and maintaining relationships within your company involve a whole different set of topics—there's enough material in that chapter to produce another ISASI paper.

Fortunately, in today's environment, the rate of major accidents has been greatly reduced. However, that can lead to complacency and an idea that there is no need for continuing formal investigative units. In my first meeting with a new boss, he questioned why the air safety investigation group still existed at all. He claimed that by then the industry knew what caused airplanes to crash and asked why we should waste our time, effort, and money going down these same paths. This shows that you need to keep people aware of your unit's mission through internal relationships and communication.

Volunteering for committee and work group tasks produces excellent learning experiences.

Internal relationships involve ensuring that you and your organization are well enough known throughout the company to get the executives to value your worth and obtain the support and cooperation necessary to do your job. I use a visual image that helps: Picture an iceberg. The actual on-site investigation work is represented by that small tip, maybe 5%, which sticks up above the water. The remaining submerged part, the other 95%, represents all the background effort that most people don't see or know about.

Besides internal relationships, many other specific areas are not being discussed here that have value. Consider: the press and other news media, lawyers, insurance people, consultants, service suppliers, military, other government agencies, and so on.

Competitors and cooperation

One final story highlights another facet of this business: You and your competitors may be arch rivals on the sales side, but when it comes to safety, it is always about cooperation and sharing.

Back in the 1990s, before PowerPoint existed and when transparencies (or viewfoils) were the vehicle of visual communication, and when Boeing and McDonnell Douglas were still separate companies and competitors, I was at a technical meeting with my counterparts from Airbus and Douglas. Yves Benoist was the Airbus investigator, and Steve Lund, the Douglas investigator. Each of us had a few minutes on the agenda to explain our organization and its approach to accident investigation and safety. We had done this several times before, and each of us knew the other's story pretty well.

The day we were due to present, Yves was called away to an accident. He handed me his stack of viewfoils and said, "Here, you've seen this before; please handle my presentation for me." I agreed. Of course, when you have viewfoils, someone needs to turn them. So here I was, the Boeing guy, giving an Airbus presentation with Steve Lund, the Douglas guy, turning the viewfoils. The impact of this cooperative spirit was not lost on our audience.

A final thought

There is a passage reportedly from St. Exupéry, that airmail poet of yesteryear, where he was lamenting the loss of pilot friends who had died in accidents, ones who he would never again see. But it applies equally well to relationships. He said: "It is idle, having planted an acorn in the morning, to expect that afternoon to sit in the shade of the oak."

So I'd like to echo his words and reinforce the thought for you, the young next generation of investigators who are emerging as our leaders of tomorrow: Start building relationships now and work hard to maintain them—attempting to accomplish this when you need them is too late. Yes, it will take some time, a bit more effort, and a little extra cost. But it is an investment that will pay dividends for the remainder of your career. And now is the time to begin.

Remember: Nobody cares if you can't dance well. Just get up and dance. ◆

From Ayn Rand's objectivism to Sherlock Holmes' deductive reasoning, investigators who think better investigate better.

Teaching New Investigators to Think

By William D. Waldock, ERAU Prescott,
and L. Pete Kelley, FAA, Air Safety Investigator

(Adapted with permission from the authors' technical paper entitled Teaching New Investigators to Think: From Ayn Rand's Objectivism to Sherlock Holmes' Deductive Reasoning *presented at the ISASI 2013 seminar held in Vancouver, B.C., Canada, on Aug. 19–22, 2013, that carried the theme "Preparing the Next Generation of Investigators." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org under the tag "ISASI 2013 Technical Papers."—Editor)*

If the goal of accident investigation is ultimately preventing accidents, what does the next generation of investigators need to have in their cerebral investigation toolkit to excel? The historical training paradigm for air safety investigators was to either start with someone near retirement in an aviation-related endeavor and make them an investigator or take the neophyte and pour in as much short-course training as possible. In both cases, much of the expertise an investigator developed was the result of on-the-job training and experience. Is there a better way? Can we apply research and experience gained from other disciplines to create mechanisms and programs to produce "expert" accident investigators much earlier in their investigation career? Teaching the technical and regulatory aspects is straightforward, but are there ways to think and "see" the makeup of accidents and the relationships that exist at an accident scene? Is accident investigation an "art" as well as a science?

In several ways, the discipline and practice of accident investigation is very similar to the study of history. Both start from the present and work backwards through time to figure out how we got where we are. Both concentrate on establishing facts, events, conditions and circumstances, outcomes and effects, and human actions and inactions. Acknowledging this, what is the minimum level of proficiency needed by a new investigator? Taking this a step further, is there a need to create processes to measure and "certify" accident investigator qualifications and skill levels?

To investigate better, think better

Investigators who investigate better think better, and much of that thinking cannot be taught in a class on accident investigation. Thomas Edison said, "The most necessary task of civilization is to teach people how to think. It should be the primary purpose of our public schools. The mind of a child is naturally active; it develops through exercise. Give a child plenty of exercise, for body and brain. The trouble with our way of educating is that it does not give elasticity to the mind. It casts the brain into a mold. It insists that the child (or adult) must accept. It does not encourage original thought or reasoning, and it lays more stress on memory than observation."

Many brilliant thinkers have pondered this conundrum:

"There is no expedient to which a man will not go to avoid the real labor of thinking."—*Thomas A. Edison*

"There is no short-cut for achievement. Life requires thorough preparation. Veneer isn't worth anything."—*George Washington Carver*

"I know that I myself have no special talent. Curiosity, obsession, and dogged endurance, combined with self-criticism, have brought me to my ideas."—*Albert Einstein*

"We should remember that one man is much the same as another and that he is best who is trained in the severest school."—*Thucydides*

"The human understanding when it has adopted an opinion, draws all things else to support and agree with it."—*Francis Bacon*

Experts, thinking, and training

The dominant researcher in the nature of expertise is K. Anders Ericsson. The preeminent source concerning the nature of expertise is *The Cambridge Handbook of Expertise and Expert Performance*, for which Ericsson is one of the editors. Geoff Colvin acknowledges that Ericsson's work of 30 years, on his own and with colleagues, provided the foundation for many of the ideas in *Talent is Over Rated*, the book Colvin wrote. This book provides a practical, applicable, and nonacademic presentation of the product of Professor K. Anders Ericsson's life work in academia, and it provided the impetus for the paper from which this article is adapted. The following synopsis was synthesized from reading the listed works, and, much like Colvin's purpose in *Talent is Over Rated*, is intended to provide the reader with generalized information concerning expertise applicable to aircraft accident investigation and the training and development of Investigators.

Experts think differently than novices. Experts think conceptually and work from primary concepts that provide context to give meaning to observed details. Similarly, they see details not observed by novices because their uniquely organized memories—developed from much combined experiences—alert them to the potential significance of seemly insignificant details. This realization both emphasizes the need for conceptual training and limits the efficacy of training without experience. It also, within this limitation, supports teaching observation skills and examples of how minute details can communicate much in causation concepts.

Unfortunately, experts do not necessarily make good trainers. Along with their unique memory patterns that combine details and conceptual meanings, they may not have retained the linkages they stepped through when they learned what they know. Novices need to step through those links.

It takes a long time to obtain expertise. Ten years is the standard lower threshold to obtain expert status in any field of endeavor. Only those who are dedicated, persistent, strive to improve, and focused or deliberate in their development reach superior or expert status. Most people plateau in their performance when they give up their commitment to seeking excellence or the effort to improve their performance or begin to believe that they have achieved expert status and have nothing left to learn.

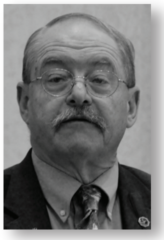


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Photo Not Available

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The most able are in the greatest danger of becoming complacent. The "greats" in any field, however, do not become complacent. This could be their most distinguishing characteristic.

Observation skills and critical thinking can and should be taught; though they may help accelerate the obtainment of expertise, they cannot replace the time, experience, and effort required to develop expertise. This said, the role and importance of logic cannot be overstated. Investigators' thinking about their thinking process while investigating is important and can be taught. It can become the basis for their self-improvement as they acquire experience.

Ayn Rand said that her epistemology was reason. Investigators need to know their basis for determining facts and methods of moving from facts to the determination of the truth concerning an event. Sir Arthur Conan Doyle's character Sherlock Holmes models the epitome of observation and reason. He could be the "ideal" investigator (minus the 5% solution, of course.) The book *Mastermind: How to Think Like Sherlock Holmes* by Maria Konnikova provides an enjoyable read that teaches what is currently known in the field of psychology concerning thinking and the mind, using examples from Doyle's Sherlock Holmes' stories. Konnikova believes that through Sherlock Holmes, Doyle provides insights into the human mind and illustrates a way of thinking that could be applied to many fields. Scientific method applied to thinking itself! The following is distilled from *Mastermind: How to Think Like Sherlock Holmes:*

Our minds naturally wander, and attention is a limited resource and it comes at the price of awareness of other things. Also, there is some effort or willful discipline involved in paying attention to something. There is no such thing as free attention; it comes at the cost of what else our attention could have been directed upon. Too often our brains choose what to pay attention to without enough conscious thought. The problem is more of a lack of mindfulness and direction, rather than a lack of attention itself. To some extent, directed attentional ability can be increased. There is a "use it or lose it" aspect to directed attentional ability. To improve our natural attentional abilities, we need to direct our thinking to be selective, objective, inclusive, and engaged.

Mindset is the beginning of selectivity. This is more than generic observation. We need to form a precise plan to maximize our limited attentional resources. This would include defined objectives and necessary elements for achieving them. There is nothing serendipitous in Holmes' approach to observation.

Objectivity is difficult because we have a tendency to see what we want to or expect to see, and we have a similar subjectivity to our thinking itself. To observe well, we must learn to separate situation from interpretation. Observations and deductions are separate and distinct steps. Explaining a situation from the beginning out loud to another person can expose where our observations are intertwined with our thoughts and perceptions and can help to disentangle the objective reality from its subjective materialization in our minds. Writing out what we believe we have learned about a situation works even better.

To fully observe, we must be inclusive and not let anything significant go unnoticed. Since our attention may shift without our awareness, it needs to be monitored. Also, as we accumulate observations, information is gained to direct attention to confirm or rule out what we have hypnotized. Analyzing whether it is consistent or inconsistent with what we have observed so far and what else we would expect to find and not find to be consistent with what we have observed so far. This creates an awareness of details to look for to confirm or rule out factors.

Engagement is important for observation and thought. Our minds need to be actively engaged. Motivation matters a lot. Without engagement and motivation, we become sloppy and can miss critical details. We feel better and perform better when we are motivated and actively involved in an activity, even when doing boring tasks. Strong personal engagement results in observing more carefully and more accurately.

Remarkably, creativity and imagination are important in observation, critical thinking, and problem-solving skills. Our expectations and experiences affect what we consider possible. "The improbable is not impossible" as Sherlock Holmes said in Chapter 6 of The Sign of Four. *"When you have eliminated the impossible, whatever remains, however improbable, must be the truth?"*

Nothing breeds overconfidence like success. Overconfidence causes us to trust our abilities too much, to underestimate others, and leads to errors in judgment. We need to develop strict thought guidelines to prevent ourselves from becoming complacent.

Dick Wood, in his article "The Basics of Aircraft Accident Investigation," says a big part of it more succinctly, "Regarding knowledge of the accident, much of the process of investigation involves eliminating things that did not happen" then focusing on finding out what did. We usually refer to this as the "Rule-Out" technique.

Is there such a thing as the "practiced eye"? Most experienced investigators spend the initial period of time at a scene just walking around the accident site, looking for what looks right, and what looks wrong, and triaging how the evidence will be worked. They work from the outside in, from the entirety to the specific, ruling out and ruling in. Is this ability the art of accident investigation? If so, can we provide the set of abilities and expertise to accident investigators earlier in their investigation career?

Current accident investigation training

Given this information, we should ask: What makes up a good aircraft accident investigator? Jerry Lederer weighed in on the characteristics of a good investigator in Flight Safety Foundation Bulletin #1 in May 1948. In an article enti-

NTSB Training Center Title Aircraft Accident Investigation	Cranfield University Aircraft Accident Investigation
Site documentation and management Operational and mechanical aspects of aircraft performance Turbine and reciprocating engines Fire and explosions Fracture recognition Weather Radar analysis NTSB "party" process Progress meetings Survival factors Human performance Survivor interviews and witness reports Working with local area responders Safety recommendations Case studies include midair collisions, in-flight fires, in-flight breakups and weather-related accidents TWA Flight 800 tutorial, examination of the reconstruction of the aircraft wreckage, and a discussion on how the NTSB undertakes major accident investigations	Legislation and regulation Appraisal of the accident site Disaster response Recovery of wreckage Collection of evidence Accident photography Hazards management on site Wreckage recovery Interviewing techniques Structures and crashworthiness Human Factors for investigators Media management Accident pathology Data recorders and their analysis Analytical techniques Systemic approach to investigation Managing investigations Liaising with victims and their families Relations with the regulatory/interested parties Developing and managing recommendations Report writing Follow-up actions Court procedures for investigators
University of Southern California–USC Viterbi Aircraft Accident Investigation	**Southern California Safety Institute–SCSI Aircraft Accident Investigation**
Investigations introduction and history Authority and theory Principles of investigation Initial actions Site safety Preliminary field investigations Investigation of aircraft fires Reciprocating engines and propellers Gas turbine engines Systems investigation Inflight breakup and midair collisions Technical assistance Analysis and report writing Flight data recorders Cockpit voice recorders Technology Understanding aircraft stability Wind shear-aerodynamics Metal and composite materials Types of material failures Identifying failures in the field Human and biomedical factors Human factors The behavioral anatomy of an aircraft accident Aeromedical role in investigation Media relations Overview of strategy	The Civil investigation process (USA) International investigation procedures (ICAO) Preparing for investigation Safety at the crash site Priorities and initial actions Investigation techniques for: engines, structures, fire, aircraft systems, instruments, and recording devices Wreckage recovery and reconstruction Photography and diagrams Midair collisions Interviewing witnesses Behavior of materials Using the global positioning satellite (GPS) system Aircraft performance factors Computers and simulation Human factors and accident pathology Analytical techniques Reporting requirements Construction of reports Investigation management

Figure 1

tled "Aircraft Accident Investigation," he states the technical qualifications and then says: "Intellectual honesty, technical competence, tact, natural curiosity, a critical mind that can formulate logical conclusions, imagination, and resourcefulness are the essential characteristics of a good investigator." Sounds very much like a combination of art and science, doesn't it?

For Civil Aeronautics Board investigators, the U.S. Office of Personnel Management identified "Common Characteristics of Air Safety Investigators" this way in GS-1815, TS-23 in August 1959: "The experience, knowledge, and good judgment of air safety investigators have a direct bearing on safety of human life, preservation of economic resources, and the future of aviation. The impact of an accident on the aviation industry and the country is far reaching. Air safety investigators must deal impartially and intelligently with individuals or groups of varying interests in the conduct of their work. They must possess the ability to express themselves clearly on technical matters and be able to work under pressure, often under hazardous conditions, in the investigation of accidents. They must be able to draw conclusions without bias from all the facts, conditions, and circumstances involved in an accident."

Frank Taylor takes it a step further in a previous *ISASI Forum* paper and defines the ideal investigator: "The ideal aircraft accidents investigator should be qualified, trained, experienced, knowledgeable, observant, inquisitive, dedicated, diligent, open-minded, independent, impartial, objective, persistent, patient, logical yet capable of lateral thinking, literate, diplomatic, fit, tireless, stable, level-headed, and much more. He or she should have humility, integrity, a good and ready sense of humor, and be able to maintain a good working relationship with all other parties involved."

The question remains, how can we produce accident investigators with those qualities?

The Flight Safety Foundation offered the first civilian course for aircraft accident investigators in New York in 1946. The topical areas taught were printed right on the certificate and look similar to most of the curricula still in use today.

A review of the current basic aircraft accident investigation professional program courses available reveals that they are all substantially similar, concentrating primarily on regulations, procedures, technical specialty areas common to basic investigation, and report writing (see Figure 1). The basic courses are intended to provide knowledge and expertise at the entry level for a new investigator, whether they are a wet-behind-the-ears fresh graduate or a 30-year airline pilot. Both are neophyte investigators. While most of the educational organizations that do this sort of training provide advanced and specialized additional courses, in most circumstances the vast majority of training and experience is on the job. Note, however, that the thinking—logic, deduction, and induction (hypothesizing)—is apparently presumed to exist and is not taught.

Figure 2

Improvements to and limits for accident investigation training

One of the greatest gaps seen in many students who come through Embry-Riddle Aeronautical University's (ERAU) programs is the lack of ability to view the entirety of the accident evidence as a combined, interrelated, and very interactive system. The thought processes that are used by an investigator who is schooled or "book smart" but who is lacking experience tend to focus on the pieces rather than understanding the totality. The other big gap that is observed relates to the ability to see what is right in front of them.

The Robertson Aircraft Investigation Lab at the ERAU Prescott campus has been enhancing several of their accident scenarios to incorporate practice intended to address both these "gaps." For example, one of the scenarios involves the crash of a glider. The aircraft is fully laid out, with ground scars, tree strikes, and even simulated blood in the cockpit. In the area just behind the pilot's seat, there is a segment of aluminum tubing clearly marked "oil." Most students never see or question that anomalous piece of evidence and are quite surprised when shown it. (See Figure 2.)

Another scenario involves an R-44 helicopter that experienced a dynamic rollover and post-crash fire. The site has been used for every professional program course run by ERAU, as well as for the undergraduate and graduate academic investigation classes, for the last two years. Thus far, only two students have observed that the wrong engine is installed in the scenario. There is a four-cylinder O-360, rather than the six-cylinder IO-540 that should be there. Again, students are surprised when this is pointed out to them. (See Figure 3.)

The Robertson lab has also begun to incorporate "deliberate practice" (a phrase coined by Dr. Ericsson) exercises into the accident investigation curriculum, using smaller, more complex scenarios designed to instill the "system" thinking techniques described previously. These scenarios are intense, focused

Figure 3

on a very specific part of the investigation process, and are designed to teach students to think outside the box to solve problems. The overall safety curriculum itself is moving toward incorporating critical thinking and logic classes as part of the core program to improve reasoning abilities. Also, to instill the "global view" of the accident process, models like C.O. Miller's 5-M's model—Management, Man, Machine, Media, Mission—is being applied to solving specific accident scenarios as a "deliberate practice" exercise for the investigation students (see Figure 4).

Other in-class possibilities to improve observation and critical-thinking abilities include using games like Mastermind and Sim City, and projects like Pascal's Candle as exercises. The practical limitations to making such thinking training available to investigators already investigating are mostly the time, money, and effort to do additional training. However, those responsible for managing aircraft accident investigation functions would wonder "Is there a need for deliberative practice concerning thinking skills" and "Do these ideas provide an important and useful tool for the investigator's mental tool box?" Perhaps the answer is elementary dear reader!

Some of the issues identified in the "think better" section above concern aspects of the development of critical thinking skills that can only come with experience. This suggests that orchestrating the development of experience after initial training and mentoring during the early development of experience would accelerate the development of expertise to some extent.

Another factor to consider is that teams do a much better and faster job correctly analyzing an accident than solo investigators. Participating in and studying the results of small team investigations usually prove this to be true.

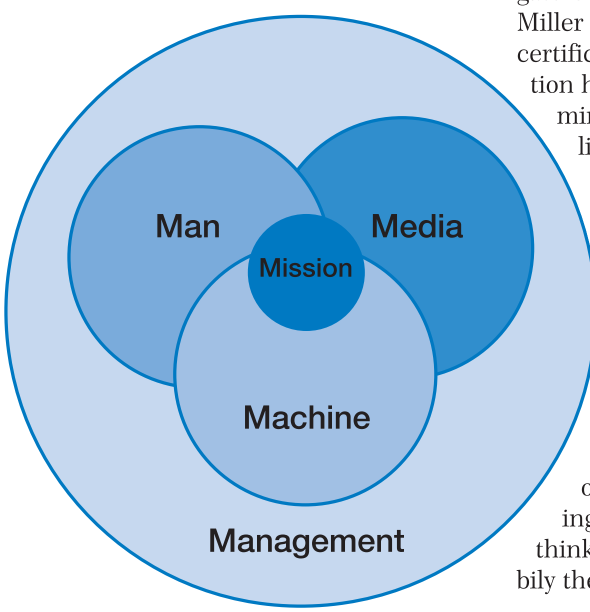

Figure 4

Our thinking is more disciplined when we speak it out in collaboration with another party. The more eyes there are, the more chance for observations to be made. The more diverse the experience of the group, the less perception bias would occur. On the creative side, teams or partnering contributes to the development of ideas concerning what the observations could mean. At a minimum, it could be concluded that new accident investigators should be teamed up with an experienced investigator, but not necessarily the most expert investigator, with the more-experienced investigator tasked to think out loud for the benefit of the less-experienced investigator.

Our learning is never complete. Ultimately, it is the consummate professional who does not become complacent, who does not become too confident, who continues to think critically about his or her thinking, who does not know it all, who will become the most expert and make the best aircraft accident investigator. It is our hope that this article has contributed to your thinking about your thinking, no matter how experienced of an accident investigator you are. And if you are, or become responsible for, the training and development of aircraft accident investigators, that it will help you to turn out better investigators.

Beyond all the previous discussion, the question arises as to whether there is a need for some form of "certification process" to ensure a minimum level of proficiency for aircraft accident investigators. Currently there is none. Chuck Miller was always a proponent of such certification. The issue with certification has merit concerning ensuring minimum ability. Should some group like ISASI consider certification?

But shifting back to the focus of this article, Sherlock Holmes was not credentialed, and Inspector Lestrade was. We all, no matter where we are in our experience level and the development of aircraft accident investigation expertise, can improve by engaging in deliberative practice concerning our observation and critical-thinking skills. Thinking about our thinking, or meta-cognition, is possibily the single most significant thing we can do to improve our performance as aircraft accident investigators. ◆

If done correctly, a modern cell phone can capture an amazing amount of information at a crash site and should become a critical tool for the modern investigator for years to come.

A New Capability For Crash Site Documentation

Supercomputers

By Major Adam Cybanski, Canadian Forces Directorate of Flight Safety, Ottawa

(Adapted with permission from the author's paper titled A New Capability for Crash Site Documentation *presented at the ISASI 2013 seminar held in Vancouver, B.C., Canada, on Aug. 19–22, 2013, that carried the theme "Preparing the Next Generation of Investigators." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org under the tag "ISASI 2013 Technical Papers."—Editor)*

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Technology has changed dramatically in the last 25 years. The memory storage capacity and speed of 1970's-era supercomputers like the Control Data 6600 and Cray have been surpassed by the modern cellular telephone. A Samsung Galaxy 2 or iPhone 4 has 2000 times the memory and approximately four times the speed of the Cray 1. In addition, the current generation of mobile devices also provides the added capabilities of audio recording, photography, video recording, mobile communications, GPS navigation, and inertial navigation.

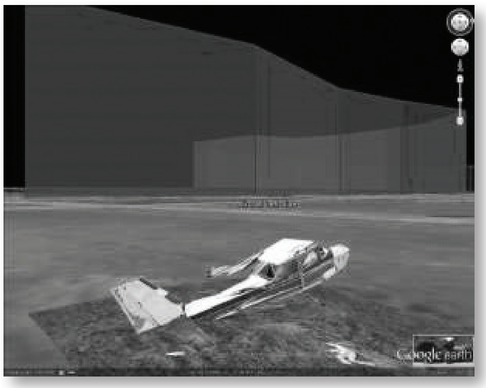
The methodology for documenting a crash site has changed little since the 1970s. New flight safety investigators are still taught to take many photos, draw a crash site diagram, and measure everything possible using a ruler and tape measure. One of the reasons this has changed so little over previous decades is because it is effective and fulfills the requirement. The incredible capabilities of consumer technology provide an opportunity to re-examine how we capture a crash site. This is exactly what was done in November 2012.

Crash exercise

A crash site exercise was conducted by DFS in Ottawa, Canada. Wreckage and miscellaneous objects were documented using total station survey equipment, GPS survey equipment, a laser scanner, and a phone. A modern cell phone was used to capture high-resolution video,

Crash exercise.

GPS-stamped photographs, and to conduct a GPS survey. During the survey, more than 400 high-resolution photos were taken, and more than 10,000 frames of video were captured by the phone. The data were analyzed in photogrammetry software and integrated into a single 3-D site model, which could be examined in Google Earth.

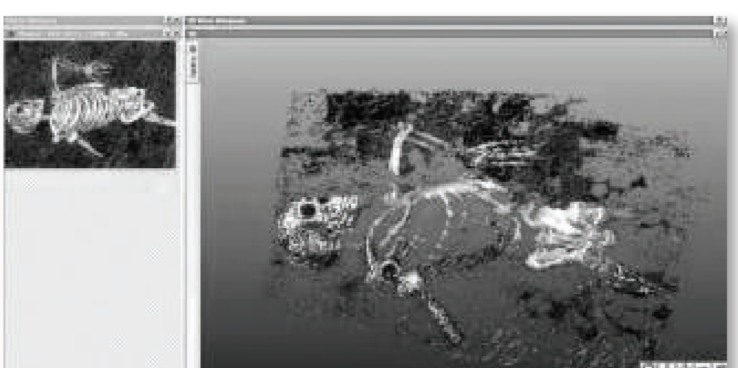


Data presentation in Google Earth.

Data presentation

In the Google Earth site model, the simulated radar flight path was added. Representative photos of the site from different viewpoints could be seen by clicking on camera icons dispersed among the site. A 3-D model of the crashed aircraft was placed at the correct location and could be examined from any perspective. Approximate distances could be measured using the ruler tool.

To illustrate the fine 3-D imaging capability for components and remains, several photos of a skeleton were stitched into a 3-D point cloud, which could also be examined from any angle. With the addition of a single-scale measurement, the measurement between any of the points could be obtained.

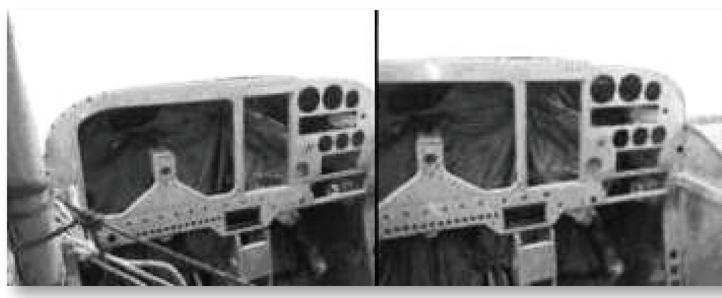


3-D point cloud.

Cell phone capabilities

A cell phone has many advantages over other methods of crash site capture. It is relatively inexpensive ($500), while surveying equipment or laser scanners can cost up to $85,000. It is available at any electronics store, and there is a very good chance that other people on the investigation will also have similar cell phones if the investigator's does not work. These phones can be used for taking notes, accessing checklists, sending e-mails, accessing maps, and many other things. A phone has a fixed focal length lens, which is important. Any time a camera lens is zoomed in or out, it must be recalibrated for photogrammetry. Using a fixed lens, such as in a cell phone, makes measurements from photographs easier and quicker. The resolution of a cell phone (eight mega pixel) is sufficient for photogrammetry, and 1080p video is more than sufficient for video analysis. By default, most phones stamp their photographs with the time and GPS location. This makes subsequent analysis much easier. Finally, the size of a cell phone is small and portable, which makes it easy to bring to any crash site.

To capture a site, two free Android applications were used. Similar programs for the iPhone exist. Tina Time-Lapse is a program that automatically takes photos at a predetermined interval. The application was set to take GPS-stamped photos in high resolution every two seconds. This meant that a large amount of photos (up to 800 in a 30-minute period) could be taken quickly simply by pointing the phone in different directions around the crash site. The volume of the phone was increased so that an audible "click" could be heard as each photo was taken. The other application used was Easy Voice Recorder Free. This application was initiated before any photos were taken, making it easy to produce a running commentary of what was being photographed. This provided easy investigator notes that could be synchronized to each photo taken.



3-D surface photographs.

Photogrammetry overview

Photos were taken at three distinct distances, for three purposes. Close-up photos were taken to capture surfaces and crushed areas and employed in deep-surface analysis to make 3-D point clouds of small areas, such as bodies, ground scars, crushed and burnt areas, etc. Medium-distance photos were stitched together to make a 3-D model of the wreckage. Distant photos were taken that included prominent land features in order to locate the wreckage pieces on the crash site. In addition to the photographs, video was taken of every surface so that nothing would be missed. Capturing the information with the phone was extremely quick, on average 10 photographs per minute.

3-D point cloud

To capture surfaces in 3D, two overlapping photos are required. The camera must be moved laterally and not turned between the photographs. If the photos are of a quality that shows sufficient texture, a 3-D model can be stitched together in about 30 minutes, once back at the lab. This model is comprised of thousands of measurable points in three dimensions and is the best way to investigate any deformations in the object.

Wreckage model

To create a large 3-D wreckage model, many overlapping photos are required. The object should be circled from left to right, and the top must be captured. Creating a traditional 3-D model is labor intensive and can take several days back at the lab. Identifiable features are marked in overlapping photos. These features (a minimum of six on each photograph) allow the software to determine the orientation and location of the camera for each shot, and then calculate the relative location of each feature in space. Joining these points can produce 3-D surfaces, which form the basis of the 3-D model.

Controlling UAV with cell phone.

Photogrammetric survey

To locate the wreckage pieces at the crash site, long-range photos are needed. Photos should include distant objects that can be seen from Google Earth, such as large trees, road intersections, towers, etc. Again, identifiable features are marked in each overlapping photograph (a minimum of six), both in the foreground and in the background. These features determine the relative camera positions and orientations, and the points can be examined in an application such as Autocad to reveal the relative position of objects.

To easily identify the location of crash components, an Android app called GPS Survey was used. This provided the position of the principal items, as well as documenting identifiable control features such as a large tower, prominent tree, road intersection, and other landmarks. The phone was able to determine the position within a few meters. If extra accuracy was needed, the methodology for differential GPS could be emulated. Continuous logging of GPS signals at one of the identifiable landmarks with a second phone, while conducting the GPS survey, might have further increased measurement accuracy.

GPS survey.

Panoramic view

Panoramic views from inside the cockpit and between the crash components were also captured and incorporated into the final Google Earth project. Double clicking on the aircraft within Google Earth takes you inside for panoramic viewing of the controls and cockpit interior. The viewpoint can be slewed left or right, up or down. Overlapping photographs are stitched together and joined at the ends to produce a continuous 360-degree strip. This image can then be formatted so that it can be viewed in a panoramic perspective.

It is critical to capture an overhead view of the components for situational awareness. This is typically done using aerial photography, but in some cases alternatives may be needed due to aircraft availability, weather, or other factors. An inexpensive UAV (Parrot Drone 2.0) was used along with a rugged camera (GoPro Silver) to capture an overhead view of the wreckage. The relatively small UAV has comprehensive integrated stabilization and was controlled by the cell phone.

Aerial view from UAV.

In addition, the UAV transmitted live HD video to the cell phone, which was recorded for later analysis. The live video also aided in effectively positioning the UAV for aerial photos and could be employed for other purposes, such as aerial search for wreckage.

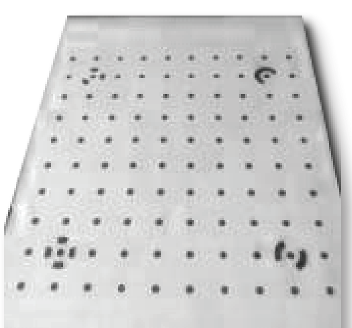
Camera calibration

A camera used by an investigator should be calibrated to improve the accuracy of photogrammetric measurements. This could be done before or after visiting the crash site. A PDF calibration

Scaling a photograph.

image (showing dots in rows) could be e-mailed to the investigator. He or she would print the image onto 8.5 x 11 paper, and then take eight photos of the paper from different angles. These photos would be sent back to the photogrammetrist, who could use them to improve the precision of crash site measurements. This calibration is not absolutely required for crash site photogrammetry but improves the accuracy of the resulting calculations.

The final 3-D models must be scaled. Without a good scaler, you cannot determine if an object is meters or millimeters across. Ideally, a tape measure should be included in most photos. An investigator can also be photographed for this purpose (if his or her height is known or subsequently measured), or GPS coordinates from the camera can be employed as a last resort.



Camera calibration sheet.

There are several applications available, such as PhotoModeler and iWitness, that can be used to conduct photogrammetric triangulation (surveying). PhotoModeler can also create 3-D dense surface models and 3-D wreckage models. The models and photographs were integrated into Google Earth for intuitive analysis by the investigators. There is a free open-source application called Insight 3D that can be used to learn how to make 3-D models from photographs.

Final thoughts

Photography has been utilized for crash investigation since the dawn of flight safety and will continue to be used for the foreseeable future. Photogrammetric analysis may be needed in an investigation but should not be construed as a routine procedure. It is important that every investigator understand how to capture crash site photos that will yield good results for photogrammetry. This will ensure that photogrammetry will be possible, if needed, and can serve as an excellent backup to other methods of site capture, such as surveys and laser scanning. If done correctly, a modern cell phone can capture an amazing amount of information at a crash site and should become a critical tool for the modern investigator for years to come.

Afterword

After the paper upon which this article was based was written, the author was called out on a helicopter crash investigation. A smartphone was employed for many purposes, including photographing and videotaping the wreckage and debris fields, making investigation notes, recording witness reenactment of the event on a tabletop model and in an aircraft cockpit, and for video playback. The utility of this portable and flexible tool will undoubtedly continue to increase with experience and time. ◆

TIPS FOR INVESTIGATORS

The following tips should be considered when preparing to document a crash site:

- Take advantage of the high capacity of memory cards by taking hundreds of GPS-stamped high-resolution photos.
- Ensure that prominent features that can be seen in Google Earth are visible in photos when possible.
- Scalers such as a tape measure or measurable objects should be visible in most photos.
- Video record the components so that they are covered from all angles.
- Conduct a GPS survey of the principal components.

Aeroplane State Awareness During Go-around (ASAGA)

Time pressure associated with limited human cognitive abilities—and thus of flight crews—is the major issue in ASAGA

By Guillaume Adam and Johan Condette, Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA)

(Adapted with permission from the authors' paper entitled Investigating Aeroplane State Awareness During Go-around (ASAGA) *presented at the ISASI 2013 seminar held in Vancouver, B.C., Canada, on Aug. 19–22, 2013, that carried the theme "Preparing the Next Generation of Investigators." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org under the tag "ISASI 2013 Technical Papers."—Editor)*

Toward the end of the 2000s, the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) observed that a number of public air transport accidents or serious incidents were caused by a problem relating to "aeroplane state awareness during go-around" (ASAGA). Other events revealed inadequate management by the flight crew of the relationship between pitch attitude and thrust, with go-around mode not engaged, but with the airplane close to the ground and with the crew attempting to climb.

Moreover, these events seemed to have some common features, such as surprise, the phenomenon of excessive preoccupation by at least one member of the crew, poor communication between crewmembers, and difficulties in managing the automatic systems.

A study was thus initiated to

- determine if this type of event is associated with a particular type of aircraft,
- list and analyze the factors common to these events, and
- suggest strategies to prevent their recurrence.

More than 15 international organizations, with a wide range of competence in terms of aviation safety, were invited to take part in the study. The complete study is available on the BEA website and includes 34 recommendations.

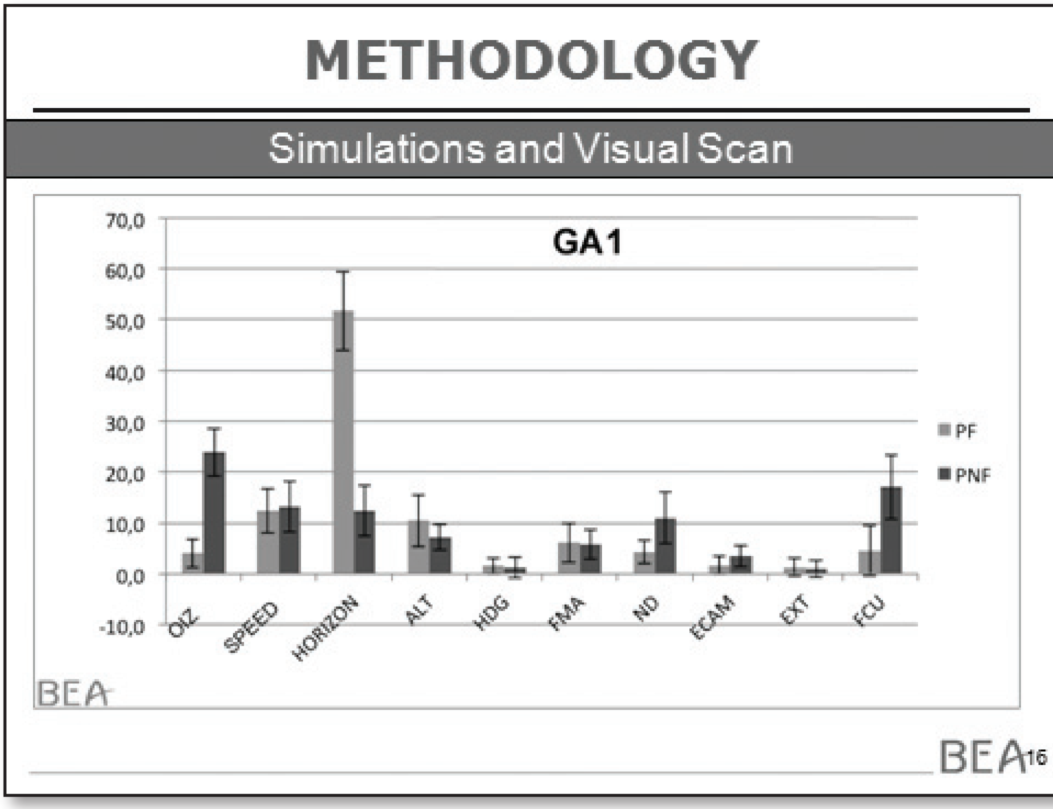
Methodology

The study focused on evaluating the robustness of the safety model for go-arounds (GAs) by using four complementary approaches.

Statistical study—Twenty-one ASAGA-type events were selected among more than 20,000 on the International Civil Aviation Organization (ICAO), Transportation Safety Board of Canada (TSB), NTSB, FAA, and BEA databases. They mainly involved Boeing and Airbus airplanes. These events were quite infrequent, but their consequences were serious. About 4% of public transport accidents that led to

***Guillaume Adam** joined the BEA as an investigator in 1994; and in October of that year he participated in the Roselawn ATR investigation. He was subsequently involved in other major public transportation investigations, either as the accredited representative or the investigator-in-charge. He left the BEA in 2002 after leading the Ops Group in the Concorde investigation and moved to the DGAC where he contributed to implementing the State Safety Program. He returned to the BEA in 2010 as head of the Public Transportation Incidents Division. Guillaume holds a master's degree in aeronautical engineering from the French National Civil Aviation School (ENAC). He also has CPL and IR/ME qualifications and is type rated on the Airbus A320.*

***Johan Condette** joined the BEA as an investigator in 2005, specializing in flight recorders and avionics. He was subsequently involved in major public transportation investigations as a Systems Group member. He took charge of the Systems Group for the accident to the A320 off the coast of Perpignan (2008) and worked as Systems Group co-chairman for the Air France Flight 447 accident investigation (2009). In 2012, he became head of the Recorders and Avionics Division in the BEA Engineering Department. Johan holds a master's degree in aeronautical engineering from the French National Civil Aviation School (ENAC) and participated in an exchange program with the Florida Institute of Technology (FIT). He also holds a PPL.*



casualties over the last 25 years were ASAGA-type. However, in 2009 and 2010, this rate rose by more than 20%.

Selection of events—16 accidents or incidents characteristic of those found by statistical means were studied. The events studied involved only twin-engine airplanes, except for one event that involved a four-engine jet airplane, and the accident or incident happened with all engines running, with one exception. With the exception of two events, very large speed and pitch attitude excursions occurred, leading to excursions in climb speed and altitude.

In all these events, disruption occurred soon after a higher level of thrust was ordered and generated potentially hazardous maneuvers. In some cases, this disruption was aggravated by other factors and surprised the crew. The reports brought to light the following factors:

- poor external visibility,
- inadequate monitoring by the pilot who is monitoring (PM),
- nose-up pitching moment generated by the engines at low speed,
- unexpected or overlooked operation of AP and/or pitch trim,
- involvement of spurious parasitic sensations (somatogravic illusions—vestibular illusions that are prevalent during high accelerations/decelerations when a pilot has no clear visual reference),
- the focus of attention,
- difficulties in reading the FMA,
- disturbance caused by ATC's role,
- lack of CRM, and
- engaging the incorrect mode during go-around.

Survey—A survey was circulated among flight crew from various French and British airlines. The objective was to draw from their experience to

- gain a better understanding of the difficulties associated with a go-around,
- collect accounts of their go-around experiences in flight and on a simulator, and
- determine, statistically, any contributory factors revealed by the survey.

Many pilot accounts thus directly confirmed the same factors and revealed the same precursors as those brought to light during investigations into ASAGA-type events. However, accident investigations have had difficulty proving these limitations due to a lack of factual data.

Visual scan and simulator sessions—The BEA undertook a series of simulator sessions in order to

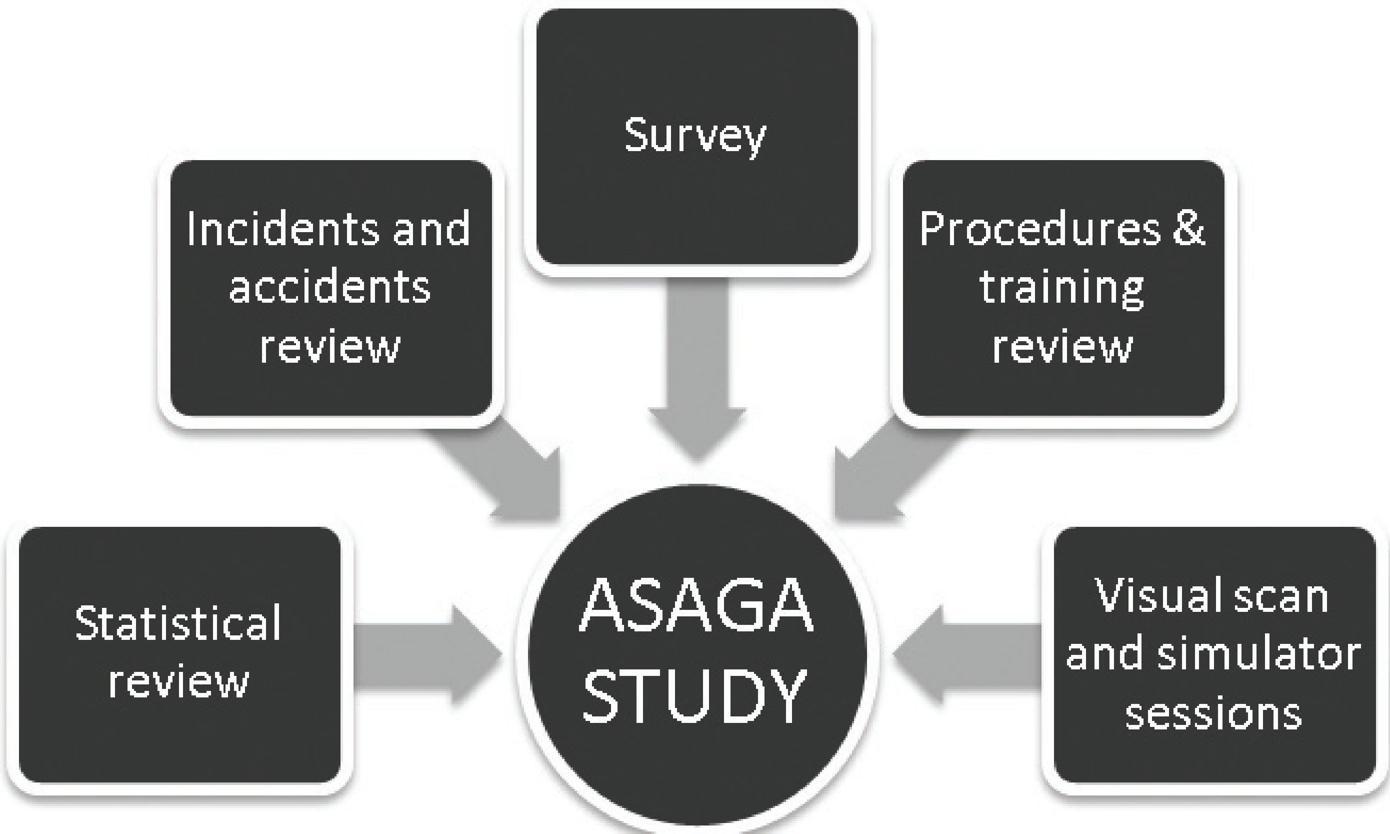
- validate the hypotheses established from the factual data collated during the study.
- increase the size of the data sample and obtain additional data that cannot be provided by incident reports or interviews.
- understand the process involved when malfunctions are triggered, notably by studying the visual scan of the two flightcrew members.

All the sessions were filmed. HD cameras were used. Both crewmembers wore an eye-tracking system. The simulations took place on B-777 and A330 FFS training simulators. The results can be seen on video on the BEA website and are available in the study.

They mainly show

- a higher workload for the PM in comparison with the pilot who is flying (PF), and the PM's nonhomogeneous visual scan.
- a high workload when time was short and a surprise effect during the go-around.
- difficulties associated with automatic systems and reading and under standing the FMA.
- the influence of ATM when a clearance is given that is different from that in the published procedure.
- the difficulty of applying the go-around procedure.
- excessive focusing of attention, in particular, on the autopilot control panel.

Simulation and visual scan.



ASAGA study.

Analysis

An ASAGA-type event is a go-around characterized by a loss of control of the flight path during the go-around. This loss of control results from loss of situational awareness by the flight crew, leading to significant speed and pitch attitude excursions. The pitch attitude excursions are significant when compared with those recommended by the SOPs, and speeds are often close to VFE, or even greater.

The initial flight path of the GA is often climbing; and then progressively and without any obvious reaction from the crew, it begins to descend and ends up either as a serious incident or an accident.

Most ASAGA-type events involve twin-engine aircraft. At the end of the flight, the aircraft is light and has a very high thrust/weight ratio. ASAGA-type events are often associated with some disruption that surprises the flight crew before or during thrust increase (e.g., unexpected ATC constraints, the engagement of automatic systems that is not in accordance with the GA, an unfavorable meteorological environment). Crewmembers thus find themselves confronted with a situation where they must perform a large number of crucial tasks (gear retraction, flight path management) under severe time pressure. These GAs are generally performed manually. However, some of the ASAGA scenarios show that the flight crew can engage the AP in an inappropriate mode.

Collisions or near collisions with the ground generally occur less than one minute after the start of the GA. In addition, in the majority of ASAGA-type accidents, CRM between crewmembers, which was not generally subject to specific remarks during the pre-GA phases, becomes dysfunctional at the time of the GA. The lack of monitoring by the PM is another commonly identified factor.

GAs with pitch trim set close to the nose-up stop

Some ASAGA-type serious incidents or accidents are characterized by a loss of control of the aircraft. First, the final approach is generally performed under AP. Following a specific event (e.g., autothrust or autothrottle disengagement, a speed or altitude selection error), the speed falls. The automatic system then compensates for this loss of speed by progressively increasing the pitch up of the THS until the AP disengages and/or the stall warning is triggered.

The flight crew performs a low-energy GA. The pitch attitude increases toward excessive values due to the application of full thrust while the position of the trim is close to the full nose-up position and the aircraft has a low initial speed. When automatic trim management is not or is no longer available, inputs on the control column/wheel to the nose-down pitch trim stop do not make it possible to counter the nose-up pitching moment generated by maximum thrust coupled with the full nose-up trim position. The pitch attitude and the angle of attack then continue to increase until the stall. The actions that allowed a few crews to recover control of the airplane before the stall were a decrease in thrust during the GA then a nose-down trim input.

Defining the problem

Conditions relating to ASAGA-type events are difficult for flight crews to detect and correct. There are, however, several common causal and contributing factors. The simulator debriefing sessions and analysis of the survey showed that pilots perform very few real GAs during their careers. Managing the GA can thus lead to many errors. During recurrent training, crews are trained in the simulator with scenarios that are not representative of ASAGA phenomena and often


Simulations and visual scan.

with a single-engine condition (i.e., with an engine failure). ASAGA-type events almost always occurred while both engines were running.

The flight crew starts the GA by pitching up, followed by application of full thrust. Acceleration due to this rapid and significant increase in thrust can create the sensation that pitch-up trim is too high. In the absence of external visual references and visual monitoring of instruments, somatogravic illusions may lead the PF to decrease the aircraft's pitch attitude to inappropriate values. These illusions are little known by crews, and current simulators do not make it possible to recreate them to train pilots to recognize them.

Managing automatic systems also poses problems. Engagement of initial modes that are different from those expected for the GA, when they are neither called out nor checked, leads the aircraft to follow an undesirable flight path. Thus, in addition to reading the FMA, monitoring the primary parameters—pitch attitude and thrust—ensures the flight crew that the automatic systems take the aircraft on a climbing flight path on the GA.

The succession of mode changes is difficult to detect, call out, and check during the GA. Time pressure associated with limited human cognitive abilities—and thus of flight crews—is the major issue in ASAGA. Flight crews must perform a large number of actions and cross-checks in a short time. The cognitive overload induced can prevent the detection of possible deviations by the PF, who is mainly focused on the PFD, and by the PM, who is performing various tasks that may divert his or her attention. Thus, a deviation, even of a significant parameter or the flight path, may not be detected by the flight crew.

In ASAGA-type events, the PM has a primordial role and a sudden high workload, greater than that of the PF. In addition, it is difficult to organize and manage. Any shortfall in monitoring can have catastrophic consequences. In the conclusions of accident reports, the lack of CRM often appears as a contributing factor. Nevertheless, CRM often works nominally and is not the subject of major comments before it becomes a disturbing element during or after a GA. Equally, in the case of an incident, CRM can operate again after the flight crew has taken control of the flight path.

Analysis of incidents and accidents, the results of simulator sessions, and the data from the survey show that it is not possible to simply limit responsibility for not following the principles of CRM to the flight crew. It is essential to find additional means to help crews recover some synergy. This "lack of CRM" appears, at the present time, to be a normal consequence when there is a situation that brings about surprise, cognitive overload, time pressure, and high stress. Evaluation of loss of situational awareness should thus include corrective measures both in terms of training and in airplane certification rules.

ATC constraints must also be taken into account: (1) Flight paths can be different from those in the published procedure prepared during the approach; and (2) Airplane performance may not be entirely compatible with some published GA procedures.

In any case, the failure to take into account the notion of flight path stabilization in a GA can increase difficulties for crews.

Thus, the success of a GA requires giving crews time to perform it and to simplify their actions. In addition, whether it be to determine the circumstances of an accident, in a discussion following a simulator session, or during an evaluation of crewmembers' monitoring abilities, a video recorder is an indispensable tool to avoid any analytical errors (retrospective bias) during an investigation.

Finally, there is the problem of fatigue at the end of a long-haul flight, which can play a role in decision-making—crews are in a psychological condition that pushes them to want to land and not perform a go-around—and the performance of the go-around.

Conclusion

The ASAGA study put into perspective and partially confirmed many factors that were dispersed among many different safety investigations. However, this grouping together of factors also brought to light some new contributory factors that had never been proven before. By using metadata, the study was undertaken like a major safety investigation and contributed to partially overturning some analytical elements that gave the flight crew excessive responsibility in accident causality. Because it was based on the analysis of the safety model, the study was able to show that the latter was not robust enough and that it needed to be strengthened. The study contains a large number of recommendations that are well supported as they take into account a large number of accidents and also involved a very wide range of those involved in the issue. (The full report may be viewed at http://www.bea.aero/etudes/asaga/asaga.) ◆

Benefits of Individual ISASI Membership

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You are an air safety professional. You may work for an airline, a manufacturer, a government, the military, an operator, or on your own. But you are a person who is dedicated to improving aviation safety, and you joined ISASI with the expectation of helping achieve that goal.

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ISASI is the only organization specifically for the air safety investigator. Our motto is "Air Safety Through Investigation." We are a growing, dynamic organization with a full range of membership.

• The yearly ISASI seminar has become a focal point for aviation safety professionals throughout the world. Attendance has steadily grown, and the presentations are state-of-the-art and meaningful.

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USING BRAIN POWER TO PREVENT THE NEXT ACCIDENT

(Continued from page 11)

mode? How do you recognize that you or your colleagues are getting into it, and how can you prevent it? Safety investigation would require a few words about that status. Accident investigation calls it "loss of…" and gives no reason. Therefore, pilot training remains traditional and thus wrong.

Air France 447 showed the combination of lack of body awareness and lack of control of one's own mental stress reaction. In addition, due to the verbal difference between the captain and the senior first officer in trying to trigger the correct motor reaction on the part of the first officer, the first officer on the controls got into a logical confusion mode. This means no more rational behavior can control the motor system.

But basically none of the three crews actually consciously discovered the hint on the artificial horizon. This effect is called "risky shift": A group of people decides differently from a single person of the group would do. However it is viewed, it is irrational decision-making due to lack of awareness training.

If the accident investigation would point out clearly any deficiencies in pilot training (why did he or she lose control of him or herself and thereafter of the airplane?) and continue to dig deeper into flight instructors and type rating instructor's roles in any accident/incident, it would possibly wake up the regulators and the pilots.

The basic training of pilots has historically grown, mainly based on manual skills, and has good and bad parts. But if it is now mainly human error, we need to prepare the next generation of accident investigators for, and improve their knowledge in, the field of human factors. ◆

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PRESIDENT'S VIEW

(Continued from page 3)

treasurer. After many decades, Tom McCarthy retired from the position; however, he remains the chairman of the Membership Committee. Ludi Benner retired from the role of chairman of the Fellow Program. Curt Lewis has assumed this position, and John Purvis was added to the board.

Also, I report with sadness that William A. Ford, design editor of *ISASI Forum* for the past 16 years, recently passed away. Bill's creativity was evident in every issue of *Forum*. The visual impact he gave to the various technical articles brought the pages of the magazine to life for many readers. His last effort for ISASI is evident in the new cover design of *Forum* as seen in this issue. Bill will be missed.

Lastly, I am pleased to report that your society is financially sound and productive. Thank you for your continued support and interest in ISASI. ◆

on

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The Birthing of ISASI's Student Membership Class

The aircraft accident investigation profession had usually been reserved for individuals with specialized backgrounds in technical fields. But in 1948, Jerry Lederer made a groundbreaking observation, which was not to "eliminate" those individuals who had a "bona-fide interest in learning about aircraft accident investigation" even though they might not possess the technical skills.

ISASI membership was not always available to university students, a challenge that was recognized in 1992 by Professors Robert Sweginnis and William Waldock. They wanted to create a new entry-level category of ISASI membership so that emerging student investigators in academic programs would be able to become part of ISASI. As a result of their efforts, a new category of ISASI membership was developed and formalized by ISASI—the Student Member.

The Prescott, Arizona, campus of Embry-Riddle Aeronautical University (ERAU) chartered the first "student section" of ISASI as a formal student organization in 1994. Officially, this student section was incorporated into the Arizona chapter of ISASI. Today the ERAU Prescott student section comprises more than 90 percent of the membership of the Arizona chapter.

The Executive Board of the student section works together with Professor Waldock, the faculty advisor. He has been president of the Arizona chapter since 1995. Meetings are held every two weeks during the regular term. The chapter has sponsored many guest speakers over the years, including Capt. Al Haynes, Greg Feith, Christine Negroni, and others from the NTSB, the FAA, and industry. Students from the chapter have participated in field trips to various safety events and facilities, and they recently toured the NTSB Academy in Washington, D.C.

ERAU has a reputation within government and industry as a leader in aviation safety education for undergraduate students, graduate students, and aviation professionals seeking quality training and certification. The Prescott campus is the nexus for ISASI students since it's home to the Robertson Aircraft Crash Investigation Laboratory.

Within its eight acres, the laboratory has eleven fully developed accident sites. Each of the scenarios is based on real crashes, with evidence recreated to the smallest detail. These accident scenarios provide realistic experiential training for the aircraft investigation student. ISASI student members play a major role in maintaining and enhancing the scenarios while gaining practical experience in investigation.

Some of the upcoming activities the ERAU-ISASI students in Prescott will undertake are "re-investigations" of several historic accident sites. Students will also participate in various tours and training throughout the United States and will host a 5K "crash-course race," which will include the Robertson crash lab. Proceeds will be applied to fees and expenses so that the students can attend the 2014 ISASI international seminar in Adelaide, Australia.

Where others see melted plastic, charred wreckage, and tragedy, the ISASI students at Embry-Riddle see a learning opportunity, a way to see order instead of chaos. These students have a passion to understand and prevent similar events and make the future a safer place.◆